ACTA ORTHOPAEDICA SCANDINAVICA

VOL. 40

ACTA ORTHOPAEDICA SCANDINAVICA

PATRIK HAGLUND
FUNDATOR

REDACTORES

IVAR ALVIK — Oslo
A. BERTELSEN — Copenhagen
STEN FRIBERG — Stockholm
K. E. KALLIO — *Helsinki*
A. LANGENSKIÖLD — *Helsinki*
H. NISSEN-LIE — *Oslo*
HARRY SØRENSEN — Odense
G. WIBERG — Lund

EDITOR
STEN FRIBERG
Stockholm

REDIGENDA CURAVIT
KNUD JANSEN
Copenhagen

VOL. 40 FASC. 1–6

MUNKSGAARD COPENHAGEN 1969

Munksgaard
International Booksellers and Publishers Ltd
47 Prags Boulevard Copenhagen S Denmark

©
MUNKSGAARD
19 0

INDEX

Vol 40 Fasc 1-6

Munksgaard
International Booksellers and Publishers Ltd
47 Prags Boulevard Copenhagen S Denmark



MUNKSGAARD
1970

PROCEEDINGS OF
THE NORDISK ORTOPEDISK FORENINGS 34th ASSEMBLY
IN NORWAY JUNE 1968

Acta orthop Scandinav 40 3–22 1969

From the Institute of Anatomy (Head Professor Bo E. Ingelmark M D)
Goteborgs Universitet Gothenburg Sweden

CORONAL CLEFT VERTEBRAE IN GROWING INDIVIDUALS

A Preliminary Report

By

SVEN REICHMANN & THORD LEWIN

Received 22 viii 67

Sagittal and coronal bands of uncalcified tissue may occur in vertebral bodies

The morphology of coronal cleft vertebrae in the foetus and newborn has been described by *Meyer Burgdorff & Klose Gerlich* (1935) *Schinz & Töndury* (1942) *Cohen et al* (1956) *Rettig* (1958) and *Tondury* (1958) *Cohen et al* have also reported on the appearance of such clefts in lateral projection roentgenograms These papers have demonstrated a considerable variation in the appearance of the cleft which is generally shaped like a horseshoe with the convexity facing forward The anterior part of the vertebral body is larger than the posterior The cleft does not always go right through the vertebral body instead it may be confined to one side or to an isolated region in the middle An otherwise complete septum is frequently bridged by a central osseous process joining the two halves of the vertebral body The tissue comprising the cleft consists of the same type of hyaline cartilage that encloses the centres of ossification of the vertebrae

Coronal cleft vertebrae occur almost exclusively in the newborn (*Tondury* 1958) and ossification of the cleft is considered to occur during the first year or two of life (*Meyer Burgdorff & Klose Gerlich* 1935 *Knutsson* 1940 *Cohen et al* 1956, *Fagerberg* 1963)

Opinions differ concerning the mechanism responsible for coronal cleft vertebra Abnormal persistence of the notochord has been held to be an important factor (*Meyer Burgdorff & Klose Gerlich* 1935 *Rathke* 1959 *Blauth & Hopf* 1960, *Zukschwerdt et al* 1960) This opinion is based upon the histological demonstration at relatively late stages of development of tissue having an apparently notochordal origin It has

moreover been stated that coronal cleft vertebrae usually occur in several segments in the same spine *Schinz & Tondury* (1942) reported that the bone nuclei of the vertebral body always develop in a uniform manner but that their shape may vary resulting in extreme cases in one anterior and one posterior part united by only a minimal bridge of bone *Rettig* (1958) ascribed the occurrence of coronal clefts to the occasional division of the bone nucleus, which is normally single

The majority of coronal clefts occur in the lumbar spine (*Tondury* 1958) though they have also been demonstrated in thoracic and cervical segments (*Knutsson* 1940, *Cohen et al* 1958 *Fagerberg* 1963) *Cohen et al* (1956) considered that coronal cleft vertebrae are more common in children with anomalies in other organs *Fagerberg* (1963) on the other hand found no increased incidence of skeletal malformations in children with coronal cleft vertebrae Instead he asserted that children with such clefts display a higher mortality *e g* in complications during pregnancy and that about 90 per cent of all children with clefts are male

The extent to which coronal clefts produce secondary states has not been investigated *Zul schwerdt et al* (1960) consider that they can cause instability in the motion segment

The present paper deals with the following questions

1 How common are coronal clefts at different ages in a postmortal series? What is their distribution in segments $L_1 - S_1$?
2 Can other structures give rise to similar roentgenograms?
3 Does ossification occur at the border between the cleft and the bone nucleus?
4 Does growth occur within a coronal cleft? Do asymmetric clefts result in asymmetric vertebrae?
5 What light does the present postnatal study throw on the genesis of coronal cleft vertebrae?

MATERIAL

The study was made on autopsy specimens comprising the segments L_1 to S_1 The specimens came from individuals autopsied in Gothenburg having died in a hospital during the collection period. Only subjects below 25 years were accepted. The drop out was less than 4 per cent for the age groups up to 16 years but could not be established for older groups No primary consideration was paid to the cause of death

The age distribution of the 132 cases is shown in Figure 4 The autopsy reports of these cases were also studied.



Figure 1 Coronal cleft vertebrae at birth seen (A) in lateral projection and (B) in axial projection A cleft in an inferior articular process is visible in (A)



Figure 2 Coronal cleft vertebrae and supernumerary bone nuclei 19 days after birth One vertebral body in (A) has a horizontal cleft in its posterior part Two separate bone nuclei are visible laterally and one medially (histologically verified) in (B) The superior contour of the lowermost vertebral body is raised in the region of the cleft



Figure 3 Radiolucent streak dividing caudally in vertebral body at birth

METHODS

The specimens were prepared as follows

1. Fixation in 10 per cent neutral formalin
2. Frontal roentgenograms using a very fine grain non screen film ("industrial film")
3. The specimen was divided down the mid line.
4. Lateral and oblique roentgenograms were taken of the two halves of the specimen The median surface was photographed with panchromatic or infra red emulsion (the latter gives a clearer picture of cartilaginous tissue in the newborn cf Figure 9)
5. The specimen was sawed into segments and vertical roentgenograms were taken of these One half of each specimen from newborn individuals was however sawed into large pieces because these can be quite conveniently embedded and sectioned as they are
6. Decalcification followed by embedding in paraplast and sectioning with a standard microtome Staining chiefly with Ehrlich s haematoxylin eosin mounting in Canada balsam. Unstained specimens were mounted in pre polymerised metachrylate

The autopsy records provided data concerning the individual s sex age cause of death and any malformations

The statistical analysis was performed with the χ_2 method even though the χ_2 hypothesis gave expected values between 0 and 5 Recent studies have shown that this method of analysis is reliable even with these expected frequencies (*Carlström* 1967)



Figure 4 Histological section in the sagittal plane from the specimen in Figure 3 The radiolucent formation corresponds to blood vessels which are surrounded by a thin one of cartilage

RESULTS

In keeping with previous investigations large variations were found in the shape of the coronal cleft (around the general form) a ventrally concave band filled with hyaline cartilage (Figures 1 and 2) No asymmetry of the vertebral body was found

Roentgenological Morphology

Most coronal clefts were visible in a lateral roentgenogram (cf Figure 13) In those cases in which the line of the cleft coincided for a considerable distance with the direction of the X rays the cleft appeared to be bordered by a thin zone of sclerotic bone Roentgenograms of specimens in the upper age groups showed that clefts in these were not as wide as in specimens from newborn individuals Raising of the chondro osseous interface is described under micromorphology

Two structures of differential diagnostic importance are vascular —



Figure 5 Supernumerary bone nucleus in a 3 year old In a lateral projection the posterior chondrous shank may be mistaken for a coronal cleft in the vertebral body

clefts and supernumerary bone nuclei in the cartilaginous zone between the vertebral body and the pedicle

A roentgenogram of a vertebral body with a vascular cleft is reproduced in Figure 3 The cleft appears as a somewhat diffuse radiolucent area with an atypical course Serial sectioning of this specimen (Figure 4) revealed the vessel surrounded by a thin zone of hyaline cartilage that continued laterally to the cartilaginous part of the vertebral body In sections that did not include the vessel the cleft differed from usual coronal clefts only in its course A similar casing of cartilage around relatively large vessels occurred in many places where blood vessels entered the vertebral body An axial view gives the best roentgenographic picture the generally short course of the vessels producing a small indentation in the periphery of the bone nucleus

The band of cartilage between the vertebral body and pedicle may contain supernumerary unattached bone nuclei (Figure 2) These develop within the cartilage which surrounds them only as a thin layer at the age of two to three years At this stage the posterior shank of cartilage may lie in the frontal plane (Figure 5) in a lateral projection it then appears very similar to a coronal cleft of the type described above

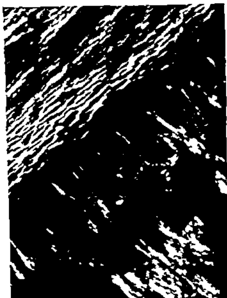


Figure 6 Polarisation microphotograph of normal endochondral zone of ossification The collagen fibres change direction at the zone of proliferation (X 118)

Micromorphology

The sclerotic border zone between the coronal cleft and bone nuclei corresponds micromorphologically to a thin layer of bone The cytological changes from the centre of the cleft to its periphery are partly the same as those in a zone of endochondral ossification A regular feature is the degenerative picture with swollen cells

Two regular morphological features in a normal zone of endochondral growth are cell proliferation and reorganisation of the collagen Cell proliferation is visible in the form of mitoses that result in the typical radial arrangement of the chondrons The direction of the collagen can be studied with a polarisation microscope a regular arrangement resulting in bi refringency with the axis along the line of the collagen (*Pfeiffer* 1949)

An ordinary zone of proliferation photographed with a polarisation microscope is shown in Figure 6 In this zone the collagen lies in the same direction as the radial chondrons (*Tonna* 1964) Outside the proliferation zone itself the collagen may lie mainly at right angles to this (Figure 6) or its direction may vary

Owing to postmortal autolysis mitoses cannot be demonstrated with certainty in this material The grouping of chondrocytes may vary in the periphery of coronal cleft vertebra (Figures 7a and 8a) In a few cases (cf the right border of the cleft in Figure 7a) the cell organisation

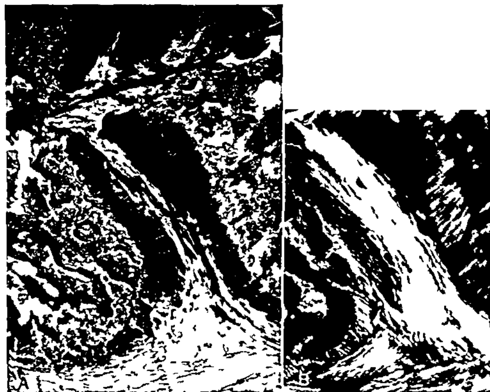


Figure 7 A Sagittal section through a coronal cleft vertebra showing normal cell organisation to the right of the cleft and a zone of weak staining in the centre (× 45)
Figure 7 B Polarisation microphotograph of the same vertebra as in Figure 7 A showing normal orientation of the collagen at the right margin of the cleft and no demarcation of the central zone collagen at the basis of the cleft (× 45)

is much the same as that found in normal zones of growth and the picture shown by the polarisation microscope is then normal too (Figure 7b) In most cases however the cells are less organised and the polarisation microscope then usually shows isolated streaks of bi refringency running in the direction of the cleft or alternatively, there may be no bi refringency (cf Figure 8 and the left border of the cleft in Figure 7)

Occasionally the upper or lower centre of ossification in the vertebral body is deformed where it connects with a coronal cleft (Figures 8 and 9) The deformation consists in the cartilaginous part of the vertebral body being raised together with the chondro osseous interface Consequently the deformation can be detected in roentgenograms (Figure 2a) Histologically these cases show an atypical transition between the



A



B

Figure 8 Sagittal section of coronal cleft vertebra as seen in the light microscope (A) and the polarisation microscope (B) No bi refringency can be detected in the margins of the cleft The upper one of the vertebral body is raised and some ir regular bi refringent streaks are visible at the junction (× 25 × 90)

cartilaginous cleft and the cartilage of the vertebral body Large clumps of cartilage cells alternate with areas of intercellular substance in which the distribution of bi refringent substance is irregular (Figure 8b)



Figure 9. Infra red photograph of median section. Hyaline cartilage appears dark. Three vertebrae display coronal clefts and deformation of adjacent parts of the chondrous tissue.

A varying amount of tissue that differs from the surrounding cartilage may occur in the centre of coronal clefts (Figure 7). Both the cells and the intercellular substance stained poorly in the specimens investigated. The cells, clearly distinguishable in the phase contrast microscope, are closely packed with no apparent grouping. They are oval in form with the major axis parallel to the line of the cleft. The polarisation microscope shows pronounced birefringency with the axis in line with the cleft. The birefringent substance does not appear to penetrate to surrounding parts of the cleft but does continue into the chondrous part of the vertebra, which suggests that it consists of collagen. One such central zone was studied in the fluorescence microscope. Its autofluorescence was bluish white, whereas the rest of the cleft emitted only slight amounts of blue light.

Figure 10 Unexplained radio lucent areas in vertebral bodies at birth



Incidence of Coronal Cleft Vertebra

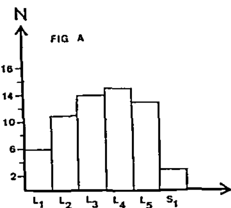
The incidence has been determined on the basis of the roentgenograms only clear cut cases being included In three cases (Figure 10) small well defined radiolucent areas were seen in the centre of vertebral bodies from newborn individuals Histological specimens have not yet been prepared in these cases and consequently the nature of these radiolucent areas has not been investigated They have therefore not been included among the cases with coronal clefts

The number of individuals with coronal cleft vertebra demonstrated roentgenologically is reported in Figure 11 The division into sub groups in age groups II and III is shown in Figure 12 It will be seen that approximately one third of all individuals below the age of 4 years in this autopsy series displayed one or more coronal cleft vertebrae in the segments L – S_1 The distribution by segments is shown in Figure 13 and the sex distribution in Table 1



Figure 9 Infra red photograph of median section Hyaline car tilage appears dark Three ver tebrae display coronal clefts and deformation of adjacent parts of the chondrous tissue

A varying amount of tissue that differs from the surrounding car tilage may occur in the centre of coronal clefts (Figure 7) Both the cells and the intercellular substance stained poorly in the specimens investigated The cells clearly distinguishable in the phase contrast microscope are closely packed with no apparent grouping They are oval in form with the major axis parallel to the line of the cleft The polarisation microscope shows pronounced bi refringency with the axis in line with the cleft The bi refringent substance does not appear to penetrate to surrounding parts of the cleft but does continue into the chondrous part of the vertebra which suggests that it consists of collagen One such central zone was studied in the fluorescence micro scope Its autofluorescence was bluish white whereas the rest of the cleft emitted only slight amounts of blue light



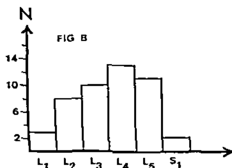


Figure 13 Distribution by segments studied in all projections (A) and in lateral projection only (B)

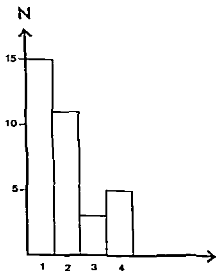


Figure 14 Number of individuals (ordinate) with different numbers of coronal cleft vertebrae in the segments L_1–S_1

The number of cases with coronal cleft vertebra are related to the cause of death in Table 3 Many individuals died of multiple causes each of which has been tabulated separately The category 'Respiratory disease' includes neonatal asphyxia The causes of death listed as "Fetus mortus ante partem" have certainly been various and are largely ascribable to complications of pregnancy which are to be investigated The cases of coronal cleft vertebra are evenly distributed among the various categories with the exception of "Tumor cerebri" and "Rh immunisation", for which the incidence of such vertebrae is significantly higher than one would expect to find with an even distribution between the causes of death The same result is obtained if the cases with coronal cleft vertebra are related only to the primary cause of death (cf Table 4)

Table 1 Distribution of cases with coronal cleft vertebra by sex and age

Sex	Age				
	0–3 years		> 3 years		
	No cleft	Cleft	No cleft	Cleft	
♂	46	23(33%)	7	0	76
♀	34	11(24%)	9	0	54
Unknown	2	0	0	0	2
	82	34	16	0	132

Incidence for age group 0–3 years.

Table 2 Incidence of coronal cleft vertebra in cases with malformations in the age group 0–3 years

Type of malformation	No of cases with malformation	Of which with coronal cleft vertebra	
		No found	No expected
All types	28	8	8
CNS anomalies	12	3	4
Skeletal anomalies	8	3	2
V O C cong	11	3	3 2
Other viscera	9	2	2.6
Mongolism	1	0	0
Multiple anomalies	4	0	1

No expected assuming an equal distribution between the groups with and without malformations.

The number of specimens with one two three or four clefts in the segments $L_1 - S_1$ is shown in Figure 14

A comparison between the occurrence of coronal cleft vertebrae and supernumerary bone nuclei in the zone of cartilage between the vertebral body and the pedicle (Figure 2) or in the inferior articular process (Figure 1a) is given in Table 5 concerning the ages in which such clefts were found As shown by the χ analysis there is a positive correlation between the occurrence of coronal cleft vertebrae and clefts in the inferior articular process Likewise if the clefts of the articular process are regarded as the result of supernumerary bone nuclei as the histology suggests and their frequency is added to the one of the pedicle zone nuclei a significant correlation exists with coronal cleft vertebrae No significant correlation could however be demonstrated between coronal cleft vertebrae and bone nuclei in the pedicle s region of growth

Table 3 Incidence of coronal cleft vertebra in relation to cause of death in the age group 0–3 years

Cause of death	No of cases	Of which with coronal cleft vertebra		χ_2
		No found	No expected†	
Intracranial haemorrhage	16	3	4 7	–
Prematurity	40	9	12	–
Tumor cerebri	2	2	0 6	4 91
Respiratory disease	43	14	13	–
Injury of birth	12	3	3 8	–
N O C	11	3	3 2	–
Accident	1	0	0	–
Cerebral anomaly	9	3	3	–
Fetus mort ante partum	27	9	8	–
Rh immunisation	2	2	0 6	4 91
Urinary tract disease	3	1	1	–
Infectious disease	9	5	3	–
Other causes	9	2	3	–
Unknown cause	3	0	1	–

Individuals with multiple causes are included in all the relevant groups.

† No expected, assuming an equal distribution between the cause of death in question and other causes

The χ value is given for the groups in which the χ analysis refuted the hypothesis

Table 4. Incidence of coronal cleft vertebra in relation to primary causes of death in the age group 0–3 years

Primary cause of death	No of individuals	Of which with coronal cleft vertebra		χ_2
		No found	No expected	
Prematurity	15	3	4.5	–
Tumor cerebri	2	2	0.6	4.91
Respiratory disease	23	9	7	–
Injury of birth	12	3	3.8	–
N.O.C.	11	3	3.2	–
Accident	1	0	0	–
Intracranial haemorrhage	16	3	4.7	–
Cerebral anomaly	9	3	3	–
Fetus mort. ante partum	13	3	4	–
Rh immunisation	2	2	0.6	4.91
Infectious disease	5	1	1.5	–
Other causes	4	2	1.2	–
Unknown cause	3	0	1	–

No expected assuming an equal distribution between the cause of death in question and other causes.
The χ_2 value is given for the groups in which the χ_2 analysis refuted the hypothesis.

DISCUSSION

According to Tondury (1958) the variation in the shape of the original nucleus which may lead to the development of a coronal cleft vertebra is entirely dependent upon the course of the vessels that grow in towards the bone nucleus. We have nevertheless made a distinction between coronal cleft vertebrae and clefts occasioned by large blood vessels because in the coronal clefts studied here such vessels were never sufficiently large or displayed such a course as to suggest that they were the cause of the cleft as such.

Coronal cleft vertebrae were found in one or more segments studied in approximately one third of all autopsy cases below the age of 4 years. This incidence corresponds to that reported by *Rettig* (1958) and is considerably higher than those published by other investigators (*Meyer-Burgdorff & Klose-Gerlich* 1935, *Cohen et al* 1958, *Fagerberg* 1961) owing to differences in the composition of the material and the methods used for the investigation.

The incidence declines from the age of 4 years onwards. Since coronal cleft vertebrae are not found in the adult it seems that they generally disappear during the fourth year of life. This is supported by the ob-

Table 5 Comparison between the incidences of supernumerary bone nuclei and coronal cleft vertebrae in the age group 0–3 years (n = 16)

Individuals with bone nucleus in the pedicle s zone of growth 7	of which with coronal cleft vertebra 4 (χ = 2 79)
Individuals with cleft in inferior articular process 5	of which with coronal cleft vertebra 4 (χ = 6 49)
Individuals with bone nucleus in the pedicle s zone of growth and cleft in inferior articular process 2	of which with coronal cleft vertebra 2 (χ = 4 91)
Individuals with bone nucleus in the pedicle s zone of growth and/or cleft in inferior articular process 10	of which with coronal cleft vertebra 8 (χ = 13 57)

servation that the cleft becomes narrower with increasing age The histological demonstration of a thin border of bone tissue and the occurrence of cell degeneration in the periphery should therefore be taken to indicate a process of ossification

If the ossification is combined with endochondral growth a coronal cleft should be able to function as a zone of growth Such growth in an asymmetric coronal cleft might be liable to result in deformation of the vertebral body In the majority of cases however there are histological differences in the chondro-osseous interface between normal zones of growth and coronal clefts In such cases the ossification appears to be preceded by true degeneration of the cleft s periphery It may be noted however that certain coronal clefts display areas that cannot be distinguished from normal zones of endochondral growth with the methods used The deformations described in the chondrous part of the vertebral body in connection with a coronal cleft may possibly express an increased proliferation in conjunction with the cleft As mentioned above no asymmetry of vertebra could be demonstrated as a result of growth in connection with a coronal cleft but in view of the infrequency of the histological phenomena reported further study of this question may be called for

Malformations in other internal organs are largely due to impairment of the normal process of development The occurrence of coronal cleft

vertebra has also been included in this category and, as mentioned above has been regarded as a result of abnormal persistence of the notochord The only possibly support for this hypothesis in the present material is the finding of central parts which stained poorly In the polarisation microscope, however their collagen is connected so naturally with that in the chondrous part of the vertebra that it appears unlikely that this tissue represents a notochordal remnant Moreover persistence of the notochord should have resulted in clefts in several segments in the same spine to a greater extent than was actually the case Since there was also no statistical correlation to anomalies in other organs which may largely be ascribed to impaired development it seems improbable that coronal cleft vertebrae in general are to be regarded as malformation Children who died from cerebral tumours or Rh immunisation displayed a significantly higher incidence than expected of coronal cleft vertebra From the investigations made to date however no explanation is possible

Individuals with coronal cleft vertebrae also display statistically inward frequency of supernumerary bone nuclei in the inferior articular process as well as such nuclei in combination with bone nuclei in the chondrous zone between the vertebral body and pedicle It therefore seems reasonable to suppose that at least the majority of coronal cleft vertebrae constitute a normal variation in the development of the vertebral body's bone nucleus

SUMMARY

The study was made on 132 autopsy cases In the age group 0–3 years about one third of the cases displayed one or more coronal cleft vertebrae in the segments L_1–S_1 Such clefts should be distinguished roentgenologically from radiolucency as resulting from large blood vessels as well as from supernumerary bone nuclei in the chondrous zone between the vertebral body and pedicle Ossification appears to be a regular micromorphological finding while proliferation appears to be impaired in most places In some cases the picture in the light microscope corresponded to the zone of normal growth and consequently coronal clefts may perhaps play a significant role in the development of asymmetrical vertebral bodies The majority of coronal cleft vertebrae probably represent an atypical pattern in the development of the vertebral body's bone nucleus

RESUME

Cette etude a ete pratiquee sur 132 cas d autopsies Dans le groupe d ages 0–3 ans il y avait dans un tiers des cas une ou plusieurs fissures coronaires des vertebres des segments $L_1 - S_1$ Ces fissures doivent etre distinguees radiologiquement des taches lumineuses resultant des larges vaisseaux sanguins aussi bien que des noyaux osseux surnumeraires dans la zone chondrale entre le corps de la vertebre et le pedoncule L ossification se revele comme une veritable trouvaille micromorphologique la proliferation apparaissant endommagee en bien des endroits Dans certains cas le tableau au micriscope lumineux correspondant a la zone de la croissance normale et il est par consequent possible que les fissures coronaires aient une influence sur le developpement de corps vertebraux asymetriques La majorite des vertebres ayant une fissure coronaire representent probablement un modele atypique du developpement des noyaux osseux du corps vertebral

ZUSAMMENFASSSUNG

Eine Studie wurde an 132 Autopsiefällen ausgefuhrt In der Gruppe 0–3 Jahre zeigte ungefahr ein Drittel der Fälle einen oder mehrere koronale Spaltwirbel der Segmente L_1–S_1 Solche Spalten sollten rontgenologisch von Röntgendurchsichtigkeit wie sie sowohl durch grosse Blutgefasse als auch durch überzählige Knochenkerne in der Knorpelzone zwischen Wirbelkorper und Stiel entsteht unterschieden werden Verknocherung scheint ein regularer mikromorphologischer Befund zu sein wahrend Proliferation in den meisten Fällen herabgesetzt zu sein scheint In einigen Fallen entspricht das Bild im leichten Mikroskop der Zone des normalen Wachstums und es kann daher möglich sein dass koronale Spalten fur die Entwicklung von asymetrischen Wirbelkörpern bezeichnend sind Die Mehrzahl von koronalen Spaltwirbeln stellen wahrscheinlich eine atypische Form in der Entwicklung des Knochenkernes des Wirbelkorpers dar

REFERENCES

Blauth W & Hopf A (1960) Ein Beitrag zur frontalen Wirbelkorperspalten. *Z Orthop* 93 494

Carlstrom E (1967) Personal communication

Cohen J Currarino G & Neuhauser E B D (1956) A significant variant in the ossification centers of the vertebral bodies. *Amer J Roentgenol* 76 469

Fagerberg S (1963) Coronal cleft vertebra in foetuses of male sex *Acta obstet gynec scand* 42 65

Knutsson F (1940) Die frontale Wirbelkorperspalte. *Acta radiol scand* 21 597

Meyer Bergdorff H & Klose Gerlich J (1935) Hemmungsbildungen im Ablauf der Wirbelsaulenverknocherung. *Arch klin Chir* 182 220

Pfeiffer H H (1949) Das Polarisationsmikroskop als Messinstrument in Biologie und Medizin. F Vieweg und Sohn Braunschweig P 9

Rathke F W (1959) Sagittale und frontale Wirbelkorperspalten Zur formalen Gesetzmassigkeit kongenitaler Wirbelkorperfehlbildungen *Arch orthop Unfall-Chir* 50 618

Rettig H (1958) Ein Beitrag zur formalen Genese frontaler Wirbelkorperspalten *Arch orthop Unfall Chir* 50 279

Schinz H. R & Tondury G (1942) Die Fruhossifikation der Wirbelkorper *Fortschr Rontgenstr* 66 253

Tonna, L. A (1964) The connective tissue framework of the femur in mice of different ages *Anat Rec* 149 559

Tondury G (1958) Entwicklungsgeschichte und Fehlbildungen der Wirbelsaule Die Wirbelsaule in Forschung und Praxis Bd. 7 Hippokrates Verl Stuttgart

Zuckschwerdt L Emminger E., Biedermann F & Zettel H (1960) Wirbelgelenk und Bandscheibe Hippokrates Verl Stuttgart

Acta orthop Scandinav 40 23-47 1969

From the Department of Orthopaedic Surgery (Head C Hirsch MD)
University of Gothenburg Sweden

INTRADISCAL MEASUREMENTS OF pH IN PATIENTS WITH LUMBAR RHIZOPATHIES

By

ALF NACHEMSON

Received 24 iii 68

Mixter & Barr s (1934) report of herniated discs causing sciatica opened up a new surgical field Since then many thousands of patients have been relieved from sciatica by the removal of a prolapsed or herniated discs and the excellent results obtained by this procedure have been verified by numerous authors (*Friberg & Hirsch* 1946 *Senning & Sjoqvist* 1947 *Waris* 1948 *Knutsson & Wiberg* 1958 *Sparup* 1960)

In some of the cases with lumbar rhizopathies and clinical symptoms simulating those of sciatica no herniated discs have been found at surgery and the results reported have been less good (*Friberg & Hirsch* 1946 *Senning & Sjoqvist* 1947 *Gottschalk & Hojgaard* 1962 *Hirsch & Nachemson* 1963)

Such negative explorations made it necessary to use more refined preoperative diagnostic procedures such as water soluble contrast myelography (*Arnell* 1949 *Knutsson* 1951) electro myography (*Shea & Woods* 1955 *Knutsson* 1951) intraosseous venography (*Schobinger Krueger & Sobel* 1961 *Amsler & Wilber* 1967) and discography (*Hirsch* 1948 *Lindblom* 1948 *Fernstrom* 1960) Thorough neurologic examinations have been made and correlated with operative findings (*Norlen* 1944 *de Morsier* 1967)

Despite all these clinical investigations almost all reports on disc surgery include a number of cases where explorations revealed no disc prolapses In a number of these cases however surgery showed connective tissue reactions around the nerve root such as adhesions and fibrous scars sometimes in connection with a rupture of the disc Also in

Supported by grants from Carin Tryggers Minnesfond

patients with disc hernia connective reactions can sometimes be seen around the nerve root (*Hirsch* 1958). In some breeds of dogs such a reaction caused by the herniated disc tissue is always severe and has been shown to be clinically important (*Hansen* 1951, 1952, *Olsson* 1951).

The pain elicited by the prolapsed disc has been said to depend not only on the actual mechanical pressure but also on an inflammatory reaction of the nerve root proper. This reaction has been thought to be caused by the degenerated disc tissue (*Lindahl* 1966).

Kelly (1956) mentioned that the theory of mechanical pressure did not fit in with a number of clinical, experimental and physiological facts, a view recently supported by *Ogienko* (1967). *Smyth & Wright* (1958), however, maintained that the pressure on the nerve root was sufficient by itself to cause sciatica but much more so if the nerve root was hypersensitized by disc herniation. They also postulated that the postoperative reaction with fibrosis around a sensitized nerve root alone could cause pain.

Herniated lumbar discs can exist in patients after recovery from a period of sciatica (*Friberg & Hirsch* 1949, *Friberg & Hulth* 1951, *Gol, Andrews & Manicom* 1966).

Histological investigations of biopsy specimens of nerve roots have been made by *Lindahl & Rexed* (1951), who showed that in seven out of ten cases operated upon for lumbar rhizopathy, inflammatory reactions (neuritis) were found in the nerve roots.

As early as 1942 *Lewis* suggested that the pain associated with tissue damage is due to the locally occurrence of abnormal chemical substances.

A low pH has been found in tissue from painful tumors but not in painless tumors, where the pH is normal (*Revici, Stoopen, Frenk & Ravich* 1949), and on the basis of their experimental work on human subjects they thought local chemical changes to be an important factor in the production of pain. They also suggested that better pain control at the level of the abnormal focus requires better knowledge of the abnormal metabolic factors responsible for the release of the substances that alter the local pH.

A reduced pH has been observed in anoxic skeletal muscle and can also result from formation of acid metabolites during heavy muscle exercise (*Irunder* 1949). In an investigation on experimentally produced skin pain *Lindahl* (1961) showed that among the various substances tested only the hydrogen ion had such pain producing pro

perties that it might reasonably be regarded as a chemical mediator of skin pain i e, an elevated hydrogen ion concentration of the same magnitude as that often seen in the body in different conditions could produce pain

It is thus possible that the pain arising from the disc hernia could be due not only to the mechanical pressure but also to an increased hydro gen ion concentration secondary to an inflammatory reaction to me chanical irritation or to the extrusion of disc tissue It might also be possible that leakage of acid metabolites through a rupture in the dor sal longitudinal ligament and in the annulus could elicit a similar reaction around the nerve roots and irritate them as well as the free nerve endings found in the ligament and in the outer part of the an nulus (*Hirsch, Ingelmark & Miller* 1963 *Jackson, Winkelmann & Bicker* 1967) The possibility of such a course of events was discussed already in 1959 by *Hirsch*

The present study was performed to find out whether pH measurements in lumbar discs could help to explain some of the clinically obscure rhizopathies in the lumbar region Measurement of the hydro gen ion concentration of prolapsed discs might also be of interest in the discussion whether the causal mechanism of the pain in disc hernia is mechanical or chemical

METHODS

The pH electrode especially constructed for this study was of needle type with a length of 145 mm (Figure 1) and a diameter of 1 2 mm The electrode consisted of purest antimony and as reference a calomel electrode was used which was placed together with the patient s finger in a solution of physiological saline A similar arrangement has been described by *Bates* (1964) and used by among others *Carter Rector Jr Campion & Seldin* (1967) Recording was made from Radiometer pH Meter 25-25SE-27 The pH electrode was calibrated with different standard buffer solutions immediately after reading the pH inside the disc and the values noted there were corrected according to the calibration-curves obtained.

The electrode was sterilized to Diglutaraldehyl 2 5 per cent for at least 2 hours before use.

At operations for lumbar rhizopathy with the routine surgical technique (*Hirsch*

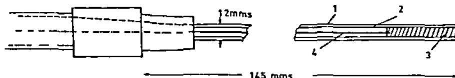


Figure 1 Schematic drawing of the needle type antimoy pH electrode used
1 Stainless steel—silver plated 2 Silica 3 Antimony 4 Iron

& *Nachemson* 1963) the nucleus pulposus of the explored interspaces was reached, after retracting the nerve root medially by inserting a larger needle (diameter 2.1 mm length 140 mm) with a pointed mandrin which then was extracted. The electrode was then inserted. When measuring in two discs two of these larger needles were inserted and the electrode was moved from one disc to the other.

The length of the electrode was necessary in order to use it in unanaesthetized subjects. On two occasions pH readings were made one day prior to surgery (cases 4 and 5) and the electrode was inserted into the nucleus with the help of an image intensifier using the posterolateral approach.

At surgery care was always taken to obtain a dry field before the disc was entered at least 1.0 cm in depth. Measurement of pH was taken after two minutes in order to achieve stable conditions. When removed careful examination invariably confirmed that no visible blood had been in contact with the electrode.

In several discs the electrode was relocated at a distance of 1–1.5 cm within the nucleus and also towards the prolapse but no difference in pH was observed.

MATERIAL

The present material consisted of measurements from one or two disc levels in 30 patients operated on for lumbar rhizopathy. In addition in one measurements were made during surgical correction for scoliosis. Two patients were measured both unanaesthetized prior to surgery and during surgery in order to check that anaesthesia did not influence the pH values. Of the patients with sciatica 10 had two discs measured and 20 one disc only. Of these discs there were 22 with prolapses, 4 with scars and adhesions only and 14 appeared normal.

All the patients with lumbar rhizopathies had a previous long enough history of sciatica warranting surgery. The pertinent clinical findings are summarized in Table 1. In all these patients myelography performed preoperatively with water soluble contrast either showed a distinct disc hernia or a short nerve root sleeve suggestive of disc hernia (*Arnell* 1949, *Knutsson* 1951). In some cases as seen from Table 1 the myelographic findings were somewhat uncertain and the reporting radiologist could not state whether the myelographic defect was due to reactive change such as fibrosis and adhesions or a small disc hernia. In these patients the history and clinical findings were severe enough to indicate surgery.

After the performance of measurements surgery was proceeded in the ordinary way i.e. disc hernias were removed or scars excised.

In some patients the myelogram was uncertain at more than one level and in these cases, which are given in the table, also a second level was explored and measured. In three of the cases the exploration was entirely negative (Nos 1, 9, 8).

Another three patients had previously been operated upon (Nos 23, 27, 30).

At each exploration the surgeon noted the amount of connective tissue around the nerve root. He found either none (0), some (+) or a large amount (+++). In the instances where no scars were found the epidural space was filled with fat and the nerve root was not adherent to the posterior part of the disc. In the patients where some scar tissue was found the space was devoid of epidural fat (as described by *Hirsch* 1958) and some fibrous tissue was seen around the nerve root which was nevertheless relatively easy to free from the disc. In the group classified as having

abundant scars and adhesions the root was clearly bound down to the disc by dense fibrous adhesions and there were absolutely no free fat in the actual space

The routine roentgenograms were scrutinized for degenerative changes and graded according to *Knutsson* (1940 1942)

RESULTS

The data obtained in 31 patients are given in Table 1 It is seen that the pH in these patients varied between 5 7 and 7 5 In those 22 discs where a prolaps was found the pH varied between 6 6 and 7 5 (mean 7 0) For this group paired correlation coefficients were evaluated between pH age of the patient preoperative duration of sciatica Lasegue s sign degenerative changes on X ray amount of connective tissue reaction around the nerve root and subjective impression of pain on the day prior to surgery

As statistically significant correlations were found between pH and degeneration (r = —0 41) between pH and pain (r = —0 46) between Lasegue s sign and pain (r = —0 46) and between age and degeneration (r = —0 52)

The most significant correlation was found between pH and the amount of connective tissue reaction found around the nerve root (r = — 0 77)

As seen from Table 2 the values in the group where no reaction was found are significantly higher than those where such a reaction was seen (t_{diff} = —5 4)

When the pH values of all prolapses were taken together and compared with the negative explorations (Table 3), no statistical difference was demonstrable Compared with the pH values of those four cases where an abundance of scar tissue and adhesions was the only findings the difference was definitely significant (t_{diff} = —6 8)

There was no correlation in this material between pH and the duration of pain prior to surgery or the age of the patient

DISCUSSION

Intravital pH measurements have demonstrated variations from pH 5 7 to 7 5 inside lumbar discs In the same individual the difference between two adjacent levels did not exceed pH 0 5 and in most instances it was much the same Most of the prolapsed discs showed values above pH 7 0 In those who also showed some connective tissue reaction around the nerve root the values were significantly lower (Table 2)

Patient no	Sex	Age (years)	Preop duration of sciatica (months)	Immediate preop impression of pain (+ ++ +++)	Neurologic deficit	Lasegue's sign (degrees)
1	♂	42	12	++	—	40
2	♀	40	—	—	—	—
3	♀	46	2	+++	+	10
4	♂	37	2	+++	+	20
5	♂	43	3	+	+	60
6	♂	42	5	++	+	60
7	♂	54	2	+++	+	60
8	♂	54	3	+++	+	60
9	♂	55	4 (24)	++	+	90
10	♀	50	4	++	+	80
11	♀	36	4	++	+	70
12	♂	41	6	+	+	60
13	♂	52	1	+++	+	20
14	♂	40	10	++	+	40

Degen changes on X ray (0 + ++ +++)	Preop myelographic findings	Operative findings	Amount of granulation tissue scars adhesions visible at explor (0 + +++)	Intra discal pH	Comments
0	neg	neg	0	7 4	pH of venous blood also measured at explor (7 3)
0	neg	neg	0	7.3	
0	---	neg	0	7.5	Scoliosis measured during Harrington correction Disc not explor
++	prolapse	prolapse covered by lig	0	6 9	
+	adhesions or prolapse?	free prolapse	+	6 6	Measured 1 day preop at L4-L5 level under local anest. pH = 6 7
+	adhesions or prolapse?	prolapse covered by lig	+	6 8	Measured 1 day preop at L4-L5 level under local anest. pH = 6 7
+	prolapse?	neg	0	6 8	
+	prolapse	free prolapse	0	7 1	
+++	prolapse?	nerve root in dense scar	+++	6 2	
++	prolapse	free prolapse	0	7 0	
+	neg	neg	0	7 3	
+	neg ?	neg	+	6 8	
++	neg	neg	0	6 9	
++	prolapse	free prolapse	0	7 0	
+	prolapse?	free prolapse	+	6 7	
++	prolapse	free prolapse	0	7 1	
++	prolapse	free prolapse	+	6 9	
+	prolapse	small prolapse covered by lig.	+	6 9	
+	uncertain	neg	0	7 4	

Patient no	Sex	Age (years)	Preop duration of sciatica (months)	Immediate preop impression of pain (+ ++ +++)	Neurologic deficit	Lasegue's sign (degrees)
15	♂	45	2	++	+	40
16	♂	57	4	+++	+	45
17	♀	27	2 (10)	+++	+	30
18	♀	39	2	+++	+	40
19	♂	53	6	+	+	neg
20	♂	42	4	+	+	50
21	♂	40	5	+	+	40
22	♂	46	1 (6)	+++	+	40
23	♂	24	4 (15)	+++	+	30
24	♂	48	[illegible]	+++	+	20
25	♀	37	4	++	+	30
26	♀	4[illegible]	6	+	−	30
27	♂	38	3	++	+	30
28	♀	6[illegible]	6	++	+	60
29	♀	42	4	+++	+	40
30	♂	51	[illegible]	+	+	80
31	♂	57	5	+	+	[illegible]0

(cont.)

Degen changes on X ray (0 + ++ +++)	Preop myelographic findings	Operative findings	Amount of *granulation* tissue scars adhesions visible at explor (0 + +++)	Intra discal pH	Comments
0	prolapse	free prolapse	0	7 5	
+	prolapse uncertain	adhesions	+++	6 0	
+	fibrous tissue?	adhesions	+++	5 7	
+	prolapse	free prolapse	+	6 7	
0	uncertain small prolapse	neg	0	7 0	
+	prolapse	free prolapse	+	7 1	
+	prolapse	free prolapse	0	7 0	
0	*prolapse*	*free prolapse*	+	6 6	
0	adhesions or prolapse	adhesions	+++	6 3	operated upon at this level 6 mths. prev
+	uncertain	neg	0	6 8	
++	prolapse	free prolapse	+	6 6	
+	neg	neg	0	7 1	
0	prolapse	prolapse covered by lig	0	7 4	
0	prolapse?	free prolapse	0	7 4	
+	adhesions or prolapse	free prolapse	0	7 4	operated upon at this level 3 yrs prev
++	protusion or prolapse	neg	0	7 2	unusual deform. arthritis of the facet joint at this level
+++	protusion	neg	0	7 2	
++	prolapse	free prolapse	+	6 8	
+	prolapse	prolap e	0	7 4	
+	neg	neg	0	7 2	operated upon at this level 3 yrs prev
++	prolapse	free prolapse	+	6 7	
+++	neg	neg	0	7 0	

Those four discs that were surrounded by more severe connective tissue reaction had a very low pH (m 6.1)

It is possible that inflammatory reactions from outside might influence the pH inside the disc but it is more likely that the elevated hydrogen ion concentration found in some of the cases the probable result of one or several of the chemical processes that occur in discs cause the connective tissue reactions by leakage through ruptures in the annulus

Table 2 Discs with prolapses

	No connective tissue reaction around the nerve root	Some connective reaction reaction around the nerve root
No	11	11
pH mean	7.2	6.8
range	6.9–7.3	6.6–7.1
T statistics	← t_{diff} = −3.4 →	

Table 3 Comparison between pH values and visible pathology

	Discs with prolapses	Discs with no visible pathologic changes	Discs with much scars and adhesions around the nerve root
No of cases	22	14	4
pH mean	7.0	7.1	6.1
range	6.6–7.5	6.8–7.4	5.7–6.3
T statistics	← t_{diff} = −0.86 →		
	←		t_{diff} = −5.8 →

van den Hooff's (1964) histochemical investigation showed that the area of histologic degeneration in the annulus fibrosus contained a considerable amount of acid mucopolysaccharides (positive Alcian Blue stain) According to *Mathews & Glagov* (1966) mechanical factors may give rise to alterations in connective tissues and increase the acid mucopolysaccharide content especially kerato-sulphate

Dahmen (1966) who also used histo-chemical methods showed that the annulus fibrosus from healthy discs contained mostly neutral mucopolysaccharides while prolapsed discs contained more acid muco-

polysaccharides *Delarue Mignot Payen & Roussel* (1955) demonstrated changes in the histo chemical reaction in degenerated connec tive tissues with lowering of the pH values and concluded that this was due to the increase in acid mucopolysaccharides

Investigations into chemical changes occurring in the nucleus pul posus and annulus fibrosus have been carried out by among others *Hirsch, Paulson, Sylven & Snellman* 1952 *Sylvén Paulson, Hirsch & Snellman* 1951 *Gardell & Rastgeldi* 1954 *Gardell & Hansen* 1959 *Hansen* 1959 *Davidson & Small* 1963 *Taylor & Little* 1965 *Dickson, Happey, Pearson Naylor & Turner* 1967 while other workers have tried to compare chemical findings of disc hernias with the normal disc aging (*Davidson & Woodhall* 1959 *Mitchell Hendry & Billewicz* 1961 *Rodighero Greco & Bertolin* 1964 *Lyons, Jones Quinn & Sprunt* 1966)

Hirsch, Paulson Sylven & Snellman (1952) showed an increase with age of the collagen/polysaccharide ratio in the human disc while *Hallen* (1960) showed an increase in the ratio kerato sulphate to chondroitine sulphate with a lowering of the total amount of poly saccharides The increase in collagen/polysaccharide ratio found by *Hirsch et al* might thus be due to the decrease in the polysaccharides with advancing According to *Buddecke & Sziegoleit* (1964) the chief acid mucopolysaccharides present in the human intervertebral discs are chondroitine 4 sulphate chondroitine 6 sulphate keratan sulphate and hyaluronic acid

Naylor (1962) demonstrated an absolute decrease of polysaccharide in the nucleus of discs which have prolapsed compared with that in age matched normal discs *Mitchell Hendry & Billewicz* (1961) on the other hand showed that the polysaccharide content of the intact nucleus increases to reach a maximum in the age group 30—40 and then declines to reach its lowest value late in life whilst there is a constant gradual increase in collagen content with age

Lyons Jones, Quinn & Sprunt (1966) also noted changes in the proteinpolysaccharide fractions of the nucleus pulposus with a decrease in polysaccharide content in both aging and prolapses and they thought that the chemical changes observed could suppress such parameters as the water binding capacity and the elasticity of the disc tissue and make it more friable and thus more predisposed to mechanical failure with subsequent extrusion of the nucleus pulposus with its decreased visco sity The ability of the disc to bind the cations should also be materially lower because of the loss of anionic sites in the molecule

The use of chondrolytic enzymes to accelerate the degenerative process beyond the stage when the lumbar discs give rise to symptoms was suggested by *Hirsch* (1959)

Chymopapain is an enzyme that has the ability to disrupt the mucopolysaccharide/protein complex of the disc and *Smith & Brown* (1967) reported good clinical results from injection of this enzyme into the lumbar discs of patients with low back pain and sciatica These authors also reported a temporary increase in urinary acid mucopolysaccharide excretion after chemo-nucleolysis The increase was found largely to be due to the chondroitine sulphate C fraction They believed this substance to consist of absorption products from the displaced disc material

If proteolytic enzymes should act on the protein/polysaccharide complex an elevated hydrogen ion concentration could occur owing to an increase in free amino acids (*Gardell* 1968) Since all connective contain such enzymes in the lysosomes this could also happen inside the disc *Tatewa* (1967) using an amino acid analyser found a significant increase of thyrosin and phenyl alanine in lumbar discs removed at surgery compared with that in age matched autopsy discs

The morphological events of discs degeneration have been described by among others *Saunders & Inman* (1940) and *Hirsch & Schajowicz* (1952) The first mentioned authors demonstrated an increasing amount of necrotic tissue inside the disc and the latter authors could demonstrate some attempts at reparation by granulation tissue via ruptures in the annuals fibrosus In this poorly vascularized area the anaerobic metabolism of the remaining fibroblasts and other cells may perhaps some times increase the lactic acid concentration and thus lower the pH

On the basis of the above investigations *Feffer* (1963) in patients suffering from acute low back pain or lumbar rhizopathies postulated acute inflammatory processes triggered off by some substances from the nucleus pulposus He also reported good results by intradiscal hydrocortisone injections Others such as *Inman* (1962) *Hendrich* (1964) and *Sakharov Zotova & Bodatchuov* (1967) instilled hydrocortisone epidurally or gave ACTH by intravenous drip (*Naylor* 1962) to such patients

In this connection the inflammatory process caused by an auto immune response to disc tissue in rabbits should be mentioned (*Bobechko & Hirsch* 1965)

As previously mentioned there has been some discussion (*Kelly*

1956 *Smyth & Wright* 1958 *Lindahl* 1966) as to whether the pain arising from disc hernias is entirely mechanical as was primarily thought by *Mixter & Barr* (1934)

We also know that in a number of patients with lumbar rhizopathies no disc hernia can be found It is thus possible that chemical irrition or inflammatory changes around a nerve root can be initiated by a leakage of acid constituents from within the disc or from the disc hernia proper pressing on the nerve root The results obtained in this study seem to support this possibility in some cases of lumbar rhizopathy In most cases of disc prolapse however the measured pH values were around neutral or above and in these the mechanical pressure theory seems to be able to explain the sciatica In three patients in this material (cases 1 9 28) the surgeon was unable to find any visible pathologic changes around the nerve roots or on the disc In the explored discs of these patients the pH varied between 6 8 and 7 4

In four patients with pH values around 6 0 there were obvious signs of inflammatory reaction around the nerve roots Preoperatively it might be possible with pH measurements to differentiate these cases from true prolapses due to the very high hydrogen ion concentration found in these discs Even with the preoperative use of water soluble contrast myelograms they cannot with certainty be distinguished from prolapses (*Hirsch & Nachemson* 1963 *Fahrenkrug Gottschalk & Hojgaard* 1964)

Actually the two cases (Nos 4 and 5) where the pH was measured one day before surgery the determination was made partly because the radiologist could not state whether the defect found was due to adhesions or to a prolapse In both cases the preoperative pH value suggested a disc prolapse which was confirmed at exploration

In cases with low pH values it is likely that chemical changes inside the disc can liberate acid substances which can explain the pain syndromes Experiments on the hydrogen ion concentration necessary to evoke pain at different locations inside the human body support this (*Revici Stoopen Frenk & Ravich* 1949 *Menkin* 1956 *Lindahl* 1961)

Some evidence in support of this line of thought was produced by the observation in this material of a significant correlation between pH and subjective impression of pain prior to surgery ($r = -0.46$) *i e* the lower the pH of the disc the more severe the subjective impression of pain

The pain sometimes persisting after removal of herniated discs has been discussed in terms of fibrous tissue reaction around the nerve

root (*Smyth & Wright* 1958, *Inman* 1962 *Nachemson* 1965 1966) In the three cases re explored in this material two had no such reaction visible and the discs had a pH of 7 4 and 7 2 respectively The third patient (No 23) showed an intradiscal pH of 6 3 and had a severe connective tissue reaction around the nerve root

Chemically no satisfactory explanation for these low pH values is available The proteolytic enzymes found in the lysosomes of connective tissue might liberate "acid amino acids from the protein/polysaccharide complex of the disc The anaerobic metabolism of the aging discs might also give rise to an elevated hydrogen ion concentration by an increased concentration of lactic acid

From a chemical point of view it is possible but not very probable that an increase in free acid mucopolysaccharides will give rise to the lowered pH found in some of the discs

Further investigations into the chemistry of lumbar discs are obviously necessary for a better understanding of the cause of the increased hydrogen ion concentration found in some discs

SUMMARY

In 40 lumbar discs in 30 patients with rhizopathy the pH was determined during surgery by a specially constructed antimony pH electrode of needle type

In 22 discs where a prolapse was found the pH varied between 7 5 and 6 6 (m 7 0) There was a significant negative correlation between pH and disc degeneration preoperative pain and most significantly the amount of connective tissue reaction around the nerve root When the pH value was below 7 0 in these discs there were also signs of some inflammatory reaction around the nerve root Hardly any such reaction was seen in discs with pH 7 0 or above In two unanaesthetized patients the pH was also measured on the day before surgery and the following day at surgery with equal results In four cases where exploration revealed that the nerve roots were covered by dense fibrous scars and adhesions the hydrogen ion concentration inside these discs was significantly higher (m pH 6 1) than in the 14 negative discs (m pH 7 1) and the 22 prolapsed discs (m pH 7 0)

The various possible chemical explanations for the high hydrogen ion concentration are outlined on the basis of previous studies on the chemistry of the lumbar discs

It is possible that acid metabolites inside the disc can leak through

ruptures in the annulus and cause some inflammatory reaction around the nerve root In four cases of very high hydrogen ion concentration the nerve root was completely embedded in a dense fibrous scar In these cases the pH was as low as or lower than that known to produce pain in human tissues This was not the case however in most of the prolapsed discs

RESUME

Cette etude a porte sur 40 disques lombaires de 30 sujets atteints de rhizopathie chez lesquels le pH a été mesure avec une electrode d anti moine de type pointu

Dans 22 disques ou on a trouve vrai prolapsus le pH a varie de 7 5 a 6 6 (moyenne 7 0) On a aussi trouve une correlation negative signifi ante entre le pH et la degeneration du disque la douleur préoperatoire et notamment la quantite de tissu conjonctif autour de la racine Quand la valeur du pH etait moins de 7 0 dans ces disques il y avait aussi des signes d une reaction inflammatoire autour de la racine

On n a vu aucune reaction pareille quand le pH etait 7 0 ou plus Dans deux cas le pH fut mesure le jour avant l operation et aussi au cours de l operation avec anesthesie totale sans difference avec anes thésie locale

Dans 4 cas ou la racine se montra entierement recouverte d un tissu dense fibrotique et adherent au disque le pH dans ces disques etait significativement inferieur (moyenne 6 1) que dans les 14 cas d exploration «negative» (moyenne 7 1) et les 22 cas de prolapsus (moyenne 7 0) Les differentes explications possibles a l augmentation des ions hydrogenes sont discutees par comparaison avec des recherches ante rieures sur la chimie des disques lombaires

Il est possible que des metabolites acides dans le disque peuvert couler par des ruptures de l anneau fibreux et causer une reaction in flammatoire autour de la racine Chez 4 sujets avec une concentration d ions hydrogenes tres augmentee la racine etait complétement en touree d une cicatrice fibrotique Dans ces cas le pH represente moins que la valeur que l on suppose pouvoir occasioner une douleur dans les tissus humains Cela n etait pas le cas dans la plupart des prolapsus de disques lombaires

ZUSAMMENFASSUNG

Bei 30 Patienten mit Wurzelschmerzen wurden in 40 Zwischenwirbel scheiben der pH Wert mit Hilfe einer spezialkonstruierten nadelfor migen Antimonelektrode gemessen

In 22 Zwischenwirbelscheiben, bei denen ein Prolaps vorlag, lagen die pH-Werte zwischen 7,5 und 6,6 (m̄ 7,0). Es lag eine signifikant negative Korrelation zwischen pH-Werten und Bandscheibendegenerationen, präoperativen Schmerzen und – am meisten signifikant – der Menge von Bindegewebsreaktion im Bereich der Nervenwurzeln vor. Waren die pH-Werte niedriger als 7,0, dann zeigten sich auch gewisse entzündliche Reaktionen um die Nervenwurzeln herum. Derartige Reaktionen wurden kaum bei pH-Werten höher als 7,0 beobachtet. Bei zwei nur örtlich betäubten Patienten wurde der pH-Wert nicht nur während, sondern auch einen Tag vor der Operation bestimmt, wobei die erhaltenen Resultate unverändert waren. Bei vier Fällen, bei denen die Exploration von dickem Narbengewebe umgebene Nervenwurzeln zeigte, lagen signifikant niedriger pH-Werte (m 6,1) als in den 14 Bandscheiben mit negativen Befunden (m 7,1) und in den 22 prolapierten Bandscheiben (m̄ 7,0) vor. Die verschiedenen möglichen chemischen Erklärungen für die erhöhte Wasserstoffjonenkonzentration werden angeführt und auf der Grundlage früher veröffentlichter chemischer Untersuchungen der lumbalen Zwischenwirbelscheiben diskutiert.

Es wird als möglich erachtet, dass saure Metaboliten der Bandscheiben durch Rupturen in den Annulus fibrosus austreten und eine gewisse entzündliche Reaktion um die Nervenwurzel herum verursachen können. Bei den 4 Fällen mit sehr niedrigen pH-Werten waren die Nervenwurzeln vollständig von dichten fibrösen Narben umschlossen. In diesen Fällen war der pH-Wert so niedrig oder niedriger als der Wert, der bekannterweise Schmerzreaktion im menschlichen Gewebe hervorrufen kann. Solch stark saures Milieu lag aber nicht bei den Fällen mit Bandscheibenprolaps vor.

ACKNOWLEDGEMENT

The author acknowledges the assistance of Engineer A. Weiss, Department of Thoracic Surgery, Karolinska Sjukhuset, Stockholm, Sweden, who constructed the pH electrode and gave valuable technical advice in the early part of this investigation.

REFERENCES

Amsler, F. R. & Wilber, M. C. (1967) Intraosseous Vertebral Venography as a Diagnostic Aid in Evaluating Intervertebral Disc Disease of the Lumbar Spine. *J. Bone Jt Surg.* 49-A, 703–712.

Arnell, S. (1949) Myelography with water soluble contrast. *Acta Radiol.* Suppl. 75.

Bates, R. G. (1964) Determination of pH. Theory and Practice, p. 257. J. Wiley & Sons, New York.

Bobechko W I & Hirsch C (1965) Auto Immune Response to Nucleus Pulposus in the Rabbit *J Bone Jt Surg* 47 B 574–580

Buddecke E & Sziegoleit M (1964) Isolierung chemis he Zusammensetzung und alterabhangige Verteilung von Mucopolysacchariden menschlicher Zwischen wirbelscheiben *Ztschr Physiol Chem* 377 6(–78

Carter N W Rector F C Jr Campion D S & Seldin D W (1967) Measurement of Intracellular pH of Skeletal Muscle with pH sensitive Glass Microelectrodes *J Clin Invest* 46 9?0–933

Dahmen G (1966) Krakhafte Veranderungen des Bindesgewebes – ihre Bedeutung *fur die Klinik und Begutachtung* pp 85 129 Ferdinand Enke Verlag Stuttgart

Davidson E A & Woodhall B (1959) Biochemical Alterations in Herniated Inter vertebral Disks *J Biol Chem* 234 2951–?954

Davidson E A & Small W (1963) Metabolism in vivo of connective tissue muco polysaccharides 1 Chondroitin sulphate C and kerato sulphate of nucleus pulposis *Biochim biophys Acta* 69 445–452

Delarue J Mignot J Payen J & Roussel A (1955) Les Lesions Degeneratives des Tissue Tendineux et Aponevrotiques *Presse Medicale* 30 605–610

Dickson I R Happey F Pearson C H Naylor A & Turner R L (1967) Variations in the protein components of Human Intervertebral Disk with Age *Nature* 215 50–53

Fahrenkrug A Gottschalk B & Hojgaard K (1964) Myelography with water soluble media in Lumbago Sciatica after operation for herniated Lumbar Disk *Acta Radiol* 2 138–144

Feffer H L (1963) A physiological approach to lumbar intervertebral disc derange ment In Adams J P editor Current practice in orthopaedic surgery 1 111–126 St Louis The C V Mosby Co

Fernstrom U (1960) A discographical Study of Ruptured Lumbar Intervertebral Discs *Acta chir scand* Suppl 258

Friberg S & Hirsch C (1946) On late results of operative treatment for interverte bral disc prolapses in the lumbar region *Acta chir scand* 93 161–168

Friberg S & Hirsch C (1949) Anatomical and Clinical Studies on Lumbar Disc Degeneration *Acta orthop scand* 19 2?2 242

Friberg S & Hult L (1951) Comparative study of abrodil myelogram and operative findings in low back pain and sciatica *Acta orthop scand* 20 303–314

Frunder H (1949) Lokale pH Anderungen des lebenden Gewebes unter Einwirkung chemischer Reizmittel *Arch ges Physiol* 251 631–644

Gardell, S (1968) Personal communication

Gardell, S & Rastgeldi S (1954) On the mucopolysaccharides of nucleus pulposus *Acta chem scand* 8 362–363

Gardell S & Hansen H J (1959) Nucleus Pulposus Kemi och Morfology *Nord Med* 29 1959

Gol A Andrews R F & Manicom R E (1966) Treatment of Disk Lesions of the Lumbar spine by Intradisk Injections of Enzymes *Sth med J* 59 1293–1296

Gottschalk B & Hojgaard, K (1962) Operatively treated patients with 1–s without demonstrable herniation of the disk *Acta neurol scand* 38 266–?70

Hallén A (1960) Extraction of Mucopolysaccharides from Connective Tissue *Acta chem scand* 14 1828–183?

Hansen H.-J (1951) A Pathologic Anatomical Interpretation of Disc Degeneration in Dogs *Acta orthop scand* 20 280–293
Hansen H -J (1952) A pathologic anatomical study on disc degeneration in dog *Acta orthop scand.*, Suppl 11
Hansen H J (1959) Comparative Views on the Pathology of Disk Degeneration in Animals *Lab Invest* 8 1242–1259
Heidrich J (1964) Ein Beitrag zur konservativen Behandlung des rezidivierenden Lendenwirbelsaulen – Syndroms mit Periduralanasthesie unter Zusatz von Kortikosteroiden *Dtsch med J* 3 101–102
Hirsch C. (1948) An attempt to diagnose the level of a disc lesion clinically by disc puncture *Acta orthop scand* 18 132–140
Hirsch C. (1951) Studies on the Mechanism of Low Back Pain *Acta orthop scand* 20 261–274
Hirsch C. (1958) Exposure of Ruptured Lumbar Discs—A technical discussion *Acta orthop scand* 28 76–80
Hirsch C. (1959) Studies on the pathology of low back pain *J Bone Jt Surg* 41 B 237–243
Hirsch C. Paulson S Sylvén B & Snellman O (1952) Biophysical and Physiological Investigations on Cartilage and other Mesenchymal Tissues VI Characteristics of Human Nuclei Pulposi during aging *Acta orthop scand* 22 175–183
Hirsch C. & Schajowicz F (1952) Studies on Structural Changes in the Lumbar Annulus Fibrosus. *Acta orthop scand* 22 184 231
Hirsch C. & Nachemson A (1963) The Reliability of Lumbar Disk Surgery *Clin Orthop* (Philadelphia) 29 189–195
Hirsch C. Ingelmark B E & Miller M (1963) The Anatomical Basis for Low Back Pain *Acta orthop scand* 33 1–17
van den Hoof A (1964) Histological Age Changes in the Annulus Fibrosus of the Human Intervertebral Disk—with a discussion of the problem of Disk Herniation *Gerontologia* 9 136–149
Inman V T (1967) Personal communication
Jackson H C. Winkelmann R K. & Bickel W H (1967) Nerve Endings in the Human Lumbar spinal Column and Related Structures *J Bone Jt Surg* 48 A 1272–1281
Kelly M (1956) Is Pain Due to Pressure on Nerves? *Neurology* 6 32–36
Knutsson F (1940) Om rontgendiagnosen av diskdegeneration i landryggraden *Nord Med* 7 1367–1369
Knutsson F (1942) The vacuum phenomenon in the intervertebral discs *Acta Radiol* 23 1 3–179
Knutsson F (1951) Lumbar myelography with water soluble contrast in cases of disc prolapse *Acta orthop scand* 20 294–302
Knutsson B & Wiberg G (1958) On surgically treated herniated intervertebral discs. *Acta orthop scand* 28 103–123
Lewis, T (1942) Pain New York, MacMillan
Lindahl O (1961) Experimental Skin Pain—induced by injection of water soluble substances in humans. *Acta physiol scand* 51 Suppl. 179
Lindahl, O (1966) Hyperalgesis of the Lumbar Nerve Roots in Sciatica. *Acta orthop scand* 37 367–374

Lindahl O & Rexed B (1951) Histologic changes in spinal nerve roote of operated cases of sciatica *Acta orthop scand* 20 215–225

Lindblom K (1948) Diagnostic puncture of intervertebral discs in sciatica *Acta orthop scand* 17 231–239

Lyons H Jones E, Quinn F E & Sprunt D H (1966) Changes in the protein polysaccharide fractions of nucleus pulposus from human intervertebral disc with age and disc herniation *J Lab clin Med* 68 930–939

Mathews M B & Glagov S (1966) Acid Mucopolysaccharide Patterns in Aging Human Cartilage *J clin Invest* 45 1103–1111

Menkin V (1956) Biochemical Mechanisms in Inflammation pp 66–98 Charles Thomas, Springfield

Mitchell P E G Hendry N G C & Billewicz W Z (1961) The Chemical Background of Intervertebral Disc Prolapse *J Bone Jt Surg* 43 B 141–151

Mixter W J & Barr J S (1934) Rupture of the intervertebral disc with involvment of the spinal canal *New Engl J Med* 211 210–215

de Morsier G (1967) Les discopathies intervertébrales *Psychiat Neurol* (Basel) 153 178–219

Nachemson A (1965) Grundlagen fur Therapieversuche mit Oxyphenbutazon bei der operativen Behandlung von lumbalen Bandscheibenhernien Symposium über die posttraumatische Entzundung und ihre Behandlung S Karger Verlag, Basel pp 151–157

Nachemson A (1966) Oxyphenbutazone (Tanderil®) in Surgery for Herniated Discs *Acta orthop scand* 37 267–275

Naylor A (1962) The Biophysical and Biochemical Aspects of Intervertebral Disc Herniation and Degeneration *Ann roy Coll Surg Engl* 31 91–114

Norlén G (1944) On the value of the neurological symptoms in sciatica for the localization of a lumbar disc herniation A contribution to the problem of the surgical treatment of sciatica. *Acta chir scand* Suppl. 94

Ogienko F F (1967) Disputable Aspects of the Mechanism of Tension Symptoms in Acute Ischialgia *Zh Neuropat Psikhiat Korsakov* 67 825–831

Olsson S E (1951) On disc protrusion in dog *Acta orthop scand* Suppl 8

Revici E Stoopen E Frenk, E & Ravich R A (1949) The Painful Focus I Physiological and Pathological Pain II The Relation of Pain to Local Physico Chemical Changes *Bull Inst Appl Biol* 1 12–38

Rodighiero G C Greco B & Bertolin A (1964) Le Modificazioni del Collagene e delle Mucoproteins nel Disco Intervertebrale Umano con il Variare dell eta *Chir Pat Sper (Milano)* 12 45–54

Sakharov L N Zotova A I & Bodatchiov V I (1967) Treatment of Ischialgia by Epidural Injections of Hydrocortisone with Procaine *Zh Nevropat Psikhiat Korsakov* 67 873–875

Saunders J C & Inman V T (1940) Pathology of the intervertebral discs *Arch Surg* 40 389–416

Schobinger R A Krueger E G & Sobel G L (1961) Comparison of Intraosseous Vertebral Venography and Pantopaque Myelography in the Diagnosis of Surgical Conditions of the Lumbar Spine and Nerve Roots *Radiology* 77 376–398

Senning A & Sjoqvist O (1947) Senresultaten vid diskbråck. En efterundersokning av 400 opererade fall. *Nord Med* 34,2 1128–1129

Hansen H.-J (1951) A Pathologic Anatomical Interpretation of Disc Degeneration in Dogs *Acta orthop scand* 20 280–293

Hansen H-J (1952) A pathologic anatomical study on disc degeneration in dog. *Acta orthop scand* Suppl 11

Hansen H-J (1959) Comparative Views on the Pathology of Disk Degeneration in Animals *Lab Invest* 8 1242–1259

Heidrich J (1964) Ein Beitrag zur konservativen Behandlung des rezidivierenden Lendenwirbelsaulen – Syndroms mit Periduralanasthesie unter Zusatz von Kortikosteroiden *Dtsch med J* 3 101–102

Hirsch C. (1948) An attempt to diagnose the level of a disc lesion clinically by disc puncture *Acta orthop scand* 18 132–140

Hirsch C. (1951) Studies on the Mechanism of Low Back Pain *Acta orthop scand* 20 261–274

Hirsch C (1958) Exposure of Ruptured Lumbar Discs—A technical discussion *Acta orthop scand* 28 76–80

Hirsch C. (1959) Studies on the pathology of low back pain *J Bone Jt Surg* 41 B 237–243

Hirsch C. Paulson S Sylvén B & Snellman O (1952) Biophysical and Physiological Investigations on Cartilage and other Mesenchymal Tissues VI Characteristics of Human Nuclei Pulposi during aging *Acta orthop scand* 22 175–183

Hirsch C & Schajowicz F (1952) Studies on Structural Changes in the Lumbar Annulus Fibrosus. *Acta orthop scand* 22 184 231

Hirsch C. & Nachemson A (1963) The Reliability of Lumbar Disk Surgery *Clin Orthop (Philadelphia)* 29 189–195

Hirsch C Ingelmark B E & Miller M (1963) The Anatomical Basis for Low Back Pain *Acta orthop scand* 33 1–17

van den Hoof A (1964) Histological Age Changes in the Annulus Fibrosus of the Human Intervertebral Disk—with a discussion of the problem of Disk Herniation *Gerontologia* 9 136–149

Inman V T (1962) Personal communication

Jackson H C Winkelmann R K & Bickel W H (1967) Nerve Endings in the Human Lumbar spinal Column and Related Structures *J Bone Jt Surg* 48 A 1242–1281

Kelly M (1956) Is Pain Due to Pressure on Nerves? *Neurology* 6 32 36

Knutsson F (1940) Om röntgendiagnosen av diskdegeneration i ländryggraden *Nord Med* 7 1367–1369

Knutsson F (1942) *The vacuum phenomenon in the intervertebral discs* *Acta Radiol* 23 173–179

Knutsson F (1951) *Lumbar myelography with water soluble contrast in cases of* disc prolapse *Acta orthop scand* 20 294–302

Knutsson B & Wiberg G (1958) On surgically treated herniated intervertebral discs *Acta orthop scand* 28 108–123

Lewis, T (1942) Pain New York MacMillan

Lindahl O (1961) Experimental Skin Pain—induced by injection of water soluble substances in humans. *Acta physiol scand* 51 Suppl. 179

Lindahl, O (1966) Hyperalgesis of the Lumbar Nerve Roots in Sciatica. *Acta orthop scand* 37 367 374

Acta orthop Scandinav 40 43-5? 1969

From the Orthopaedic Hospital Aarhus Denmark
(Head Professor Eivind Thomasen M D)

RECURRENT ANTERIOR DISLOCATION OF THE SHOULDER TREATED BY THE EDEN HYBINETTE OPERATION

Follow Up on 78 Cases

By

ARNE ØSTER

Received 13 xii 67

INTRODUCTION

Recurrent anterior dislocation of the shoulder has been treated by many different operations

With the exception of two cases treated by the *Bankart* (1938) operation all patients admitted to the Orthopaedic Hospital Aarhus Denmark have been treated since 1938 by the method of *Eden* (1918) and *Hybinette* (1932) in the modification of *Magnus* (1932) as described by *Thomasen* (1944)

In an attempt to determine the effectiveness of this method the material was subjected to an analysis and follow up

MATERIAL

From 1938 through 1964 the Eden-Hybinette (E-H) operation was performed on one shoulder in 86 patients and on both shoulders in 5 patients making a total of 96 cases In 4 the operation was done twice because of recurrence after the first The analysis is based upon the condition before the first operation

Of the 96 cases 65 were in males and 31 in females. In 47 cases the right shoulder was affected in 49 the left. The age at which the first dislocation occurred was in 71 cases under 30 years (74 per cent) in 32 cases under 20 years (33 per cent) Only one patient was under 15 (12 years) at the time of the primary dislocation

The primary dislocation was sustained in sport, in traffic accidents or in accidents *during work in 27 21* and 23 cases respectively *while it was due to epileptic seizures* and accidents in the patients homes in 9 cases each and in 7 cases there had been no known trauma

Of 11 patients with dislocation of both shoulders 5 were operated upon bilaterally



Figure 1 The bean sized remainder of the bone graft is located beneath and in front of the scapular neck

DISCUSSION

The age distribution of the patients at the time of the primary dislocation corresponds to that reported in previous publications (*McLaughlin & McLellan* 1967) The duration of immobilization after the primary dislocation less than one week in the majority of the cases may have been inadequate

94 per cent of the cases in the present study showed a posterior capital notch This is in keeping with *Hermodsson* (1934) *Palmer & Widen* (1948) give the posterior capital notch the major part of the blame for the recurrences

The findings of injury to the anterior supporting structures are in conformity with earlier publications (*Hybinette* 1932, *Lavik* 1961) *Willner* (1964) found a positive correlation between the degree of depression of the edge of the glenoid cavity the number of dislocations the ease with which they occurred and with which they were reduced again

McLaughlin (1960) emphasizes that damage to the gleno-humeral ligaments and formation of an anterior pouch of the joint space make forward displacement of the humeral head possible Arthrographic studies by *Reeves* (1966) showed constant enlargement of the subscapular bursa and either absence of the glenoid labral outline or an enlarged opening to the subscapular bursa in cases of recurrent dislocation of the shoulder

The original idea in using a bone graft was to build out the glenoid cavity to prevent forward dislocation of the humeral head (*Eden* 1918 *Hybinette* 1932) However it has been substantiated by *Jakobsson* (1949) that a graft on a level with the glenoid rim gives results as good as a graft projecting laterally beyond that level The fact that the

graft diminishes and very often disappears in 1–2 years has further convinced the author that the mission of the graft is rather to form scarification and shrinkage of the capsule than to give simple mechanical support to the joint

However the importance of scarification in preventing redislocations might explain the strange fact that none of the present cases operated upon by less experienced surgeons had had redislocations *Hippocrates* treated recurrent anterior dislocation of the shoulder by inserting red hot iron anterior to the shoulder joint apparently to provoke scarification *Watson Jones* (1948) stresses the importance of operative exposure of the anterior joint structures and subsequent re suture stating that the specific repair of labral lesions—which he found in 70 per cent—is of less value in preventing redislocation

Danis (1966) fills the anterior synovial pouch with iliac grafts introduced directly into the joint through an axillary approach

In the present material 18 per cent of the re examined cases have redislocated This is in agreement with *Eigenthaler* (1950) and *Hedman* (1952) while *Jakobsson* (1949) *Lavik* (1961) and *Schwarzer* (1966) have reported far better results (Table 4) *Jackson Day MacDonnell & Pedersen* (1966) had no redislocations after 5 years follow-up on their series of Bankart and Magnusson operated shoulders but a high rate of redislocations after more than 13 years follow up (Table 4)

Table 4 Some follow up studies on E–H materials For comparison long term studies on Magnusson and Bankart materials

Author	Year of public	Method	Follow up period (years)	No of oper cases	No of re exam cases	No of redisloc cases	% redisloc cases
Jakobsson	1949	E.–H	1–10	43	43	0	0
Eigenthaler	1950	E.–Brun	2	41	27	6	22
Hedman	1952	E.–H	1.5–20	37	31	6	19
Lavik	1961	E.–H.	1.7–10	22	22	1	4
Schwarzer	1966	E.–H	5–12	19	14	0	0
Present material		E.–H	0.5–27	96	78	14	18
Day MacDonnell & Pedersen	1966	Magnusson	13–20	24	14	2	14
Day MacDonnell & Pedersen	1966	Bankart	13–20	17	9	3	33



Figure 1 The bean sized remainder of the bone graft is located beneath and in front of the scapular neck.

DISCUSSION

The age distribution of the patients at the time of the primary dislocation corresponds to that reported in previous publications (*McLaughlin & McLellan* 1967) The duration of immobilization after the primary dislocation less than one week in the majority of the cases may have been inadequate

94 per cent of the cases in the present study showed a posterior capital notch This is in keeping with *Hermodsson* (1934) *Palmer & Widen* (1948) give the posterior capital notch the major part of the blame for the recurrences

The findings of injury to the anterior supporting structures are in conformity with earlier publications (*Hybinette* 1932 *Lavik* 1961) *Willner* (1964) found a positive correlation between the degree of depression of the edge of the glenoid cavity the number of dislocations the ease with which they occurred and with which they were reduced again

McLaughlin (1960) emphasizes that damage to the gleno-humeral ligaments and formation of an anterior pouch of the joint space make forward displacement of the humeral head possible Arthrographic studies by *Reeves* (1966) showed constant enlargement of the subscapular bursa and either absence of the glenoid labral outline or an enlarged opening to the subscapular bursa in cases of recurrent dislocation of the shoulder

The original idea in using a bone graft was to build out the glenoid cavity to prevent forward dislocation of the humeral head (*Eden* 1918 *Hybinette* 1932) However it has been substantiated by *Jakobsson* (1949) that a graft on a level with the glenoid rim gives results as good as a graft projecting laterally beyond that level The fact that the

Un reste de la greffe osseuse etait visible aux rayons X dans la moitie des cas radiographies qu il y ait nouvelle dislocation ou non

En s appuyant sur la litterature il est conclu que l effet de l operation peut etre cause par le scarifice des structures de l articulation anterieure *Cela peut expliquer pourquoi des chirurgiens inexperimentes obtiennent de meilleurs resultats que des chirurgiens experimentes*

Il n est pas possible de trouver dans la litterature une methode donnant des resultats appreciablement meilleurs apres une tres longue periode d observation

ZUSAMMENFASSUNG

Eine Studie von 96 Fallen von recidivierender Schultergelenksverrenkung die nach der Methode von *Eden Hybinette* operiert worden waren wurde vorgelegt 78 Falle wurden nach einer Beobachtungzeit von ½–27 Jahren wiederuntersucht 14 Falle hatten eine Wiederverrenkung *10 innerhalb der ersten 2 postoperativen Jahre und dann gewohnlich* spontan Vier der 14 Falle waren mittels der E-H Methode erfolgreich reoperiert worden und 5 litten fortgestzt an Luxationen wahrend die restlichen 5 sich zur Zeit der Nachuntersuchung nicht um ihre Schulter bekummerten

Ein Rest der Knochenspange war in der Halfte der mittels Rontgenstrahlen untersuchten Falle sichtbar gleichgultig ob Reluxation entstand oder nicht

Mit Unterstutzung aus der Litteratur schliesst man dass der Effekt der Operation in der Skarifizierung der vorderen Gelenkspartien begrundet sein muss Dies erklart weshalb unerfahrene Chirurgen bessere Resultate erzielen als erfahrene

In der Litteratur kann man keine Methode mit signifikant besseren Ergebnissen nach einer langen Beobachtungszeit finden

REFERENCES

Bankart A S B (1938) The Pathology and Treatment of recurrent Dislocation of Shoulder Joint *Brit J Surg* 26 23

Danis A (1966) Technique nouvelle du traitement de la luxation recidivante de l epaule *Acta Orthopaed Belg* 32 729

Day A Jackson Mac Donnell J A & Pedersen H E (1966) Recurrent Dislocation of the Shoulder A comparison of the Bankart and the Magnusson procedures of 16 years *Clin Orthopaed* 45 123

Eden R (1918) Zur Operation der habituellen Schulterluxation unter Mitteilung eines neuen Verfahrens bei Abriss am inneren Phannenrande *Deutsches Z f Chirurgie* 144 269

Eigenthaler L. (1950) Behandlung habitueller Schulterluxationen *Wien Med Wschr* 100 265

Hedman D (1952) The Eden Hybinette Operation for recurrent Dislocations of the Shoulder A clinical follow up study *Acta chir scand* 104 65

Hermodsson M S (1934) Rontgenologischen Studien uber die traumatischen und habituellen Schultergelenkverrenkungen nach vorn und nach untern *Acta Radiol* Suppl. 20

Hybinette S (1932) De la transplantation d un fragment osseux pour remedier aux luxations recidivantes de l epaule constation et resultats opératoires. *Acta chir scand* 71 411

Jakobsson A (1949) On recurrent Dislocation of the Shoulder Joint. *Acta orthop. scand* 18 284

Lavik K (1961) Habitual Shoulder Luxation Eden Hybinette Operation *Acta orthop scand* 30 251

Mac Laughlin H L. (1960) Recurrent Dislocation of the Shoulder I Morbid Anatomy *Amer J Surg* 99 628

McLaughlin H L. & Mac Lellan D I (1967) Recurrent anterior Dislocation of the Shoulder II A comparative Study *J Trauma* 7 191

Magnus (1939) Zur Behandlung der habituellen Schulterluxation *Zentralblatt für Chirurgie* 59 2909

Palmer I & Widen A (1948) The Bone block method for recurrent Dislocation of the Shoulder Joint *J Bone Jt Surg* 30 B 53

Reeves B (1966) Arthrography of the Shoulder *J Bone Jt Surg* 48 B 424

Schwarzer R. (1966) Die operative Behandlung der habituellen Schulterluxation nach Eden-Hybinette. *Z Art I Fortbil I* (Jena) 60 44

Thomasen L. (1944) *Habitual dislocation of the Shoulder A study on the nature* and treatment of the disease including remarks on traumatic dislocations. *Acta orthop scand* 15 206

Watson-Jones R (1948) Note on recurrent Dislocation of the Shoulder Joint. *J Bone Jt Surg* 30 B 49

Willner S (1964) Observation of operative Treatment of residual Dislocation of the Shoulder *Acta orthop scand* 35 132

Acta orthop Scandinav 40 53-61 1969

From the Orthopaedic Hospital Aarhus Denmark.
(Head Professor Eivind Thomasen MD)

CONGENITAL DISLOCATION OF THE HIP

Results of Early Treatment

By

HANS N GREGERSEN

Received 20 xii 67

Closed reduction of simple congenital dislocation of the hip (c d h) with retention in a "frog position (flexion abduction and external rotation in the hip joints) was introduced by *Lorenz* in 1895 This treatment was usually carried out at the age of 2-3 years frequently it was traumatizing to the hip joints it required anaesthesia and it was prolonged In 1936 *Ortolani* described the reduction phenomenon which is recognized as a sure sign of c d h in newborns Thereafter it was possible to treat these patients at a far earlier age than previously Nevertheless there was disagreement as to when and how to treat patients with c d h for several years after *Ortolani's* observation After the great efforts to receive these patients for treatment as early as possible made by *von Rosen* and others it has been accepted that early treatment by closed reduction is the treatment of choice (*von Rosen* 1957 1962 1965 *Ponseti* 1961 *Barlow* 1962 *Borghlin* 1962 *Vulpius* 1964 *Schwartz* 1965)

METHODS

From May 1 1958 to December 31 1966 a total of 59 patients in whom the diagnosis of c.d.h. was made within the first 10 days of life were treated in the Orthopaedic Hospital, Aarhus. In all cases the diagnosis was based upon the presence of Ortolani s phenomenon and/or instability in the hip joints. The first 5 patients were examined by arthrography confirming the diagnosis. A few patients had other X rays exami nations, but without diagnostic significance.

In all cases the treatment was started a short time, i.e. a maximum of 9 days, after the diagnosis was made All the patients were treated in a felt padded hip plaster cast with the lower limbs in the "frog position" i.e. Lorenz position I (Figure 1) The plaster was changed at 2-3-week intervals The period of plaster



Figure 1 The plaster cast in a 6 week old girl

treatment was in practically all cases around 13 weeks. Thereafter the first 4 patients were kept in a position of abduction for 7–37 weeks. Two of these patients were kept in plaster in the Lorenz I position for 25 and 22 weeks respectively one because of a questionable subluxation and the other one because of subluxation after the first treatment period The remaining 52 patients were not treated by a period of abduction their lower limbs being left free after removal of the hip cast. In 3 of these patients further treatment was required Their histories will be reported in brief outline

1 B 126542. After treatment in a hip cast for 13 weeks the hips were clinically and radiologically normal About 4 months later the head of the right femur was found to be dislocated so that after closed reduction the baby was kept in plaster in the Lorenz I position for another 10 weeks. Thereafter abduction bed for 16 months At follow up at the age of 4 years both hips were found to be normal clinically as well as radiologically

2 B 132563 After treatment in a hip cast for 13 weeks the left hip was found to be dislocated and there was severe dysplasia of the acetabulum. The baby was kept in plaster in the Lorenz I position for another 13 weeks followed by a plaster cast keeping the hips in abduction and internal rotation—the Lorenz II position—for 1 weeks and thereafter in an abduction bed for 5 months. Even then the left hip remained dislocated and the acetabulum dysplastic At the age of 18 months operative reduction was done by a Lance acetabuloplasty and derotation osteotomy of the upper end of the femur

3 B 133210 After treatment in a hip cast for 13 weeks the hips were normal clinically as well as radiologically Four months later the right hip was found to be dislocated so that the baby was kept in an abduction bed for 9 months At follow up at the age of 2 years the hips were normal

The follow up was performed in the Department, and comprised a clinical as well as an X ray examination. In the clinical examination special emphasis was laid on complaints, gait, mobility in the hip joints, and shortening of the legs. In the X rays: Situation, size and bony structure of the femoral head, appearance of the acetabulum and orientation of the upper end of the femur in relation to the femoral diaphysis.

RESULTS

In all the cases the diagnosis had been made within the first 10 days of life—average 2nd day of life. At the institution of treatment the age averaged 6 days.

Tables 1 and 2 list the distribution of the dislocations by sex and side affected.

Table 1. Sex ratio

	Number of patients	Ratio
Females	50	5.5
Males	9	1

Table 2. Distribution of dislocations by side affected

	Left	Right	Bilateral	Total
Number of dislocations	27	10	22	81

41 patients with 54 dislocations were included in the follow up. The remaining 18 patients had not started walking at the time of the follow up and were therefore left out.

At follow up the age ranged from 1 year 7 months to 8 years 8 months, average 4 years 8 months.

Complaints. No patient had any complaints from the hips.

Gait. Normal in 40 patients. One patient could not walk at follow up because of re dislocation in the hip joint. Thus 97.5 per cent of the patients had a normal gait.

Shortening. Three patients with unilateral dislocation showed shortening of the homolateral leg as compared with the unaffected one. In two patients the shortening was 1½ and ½ cm and caused by varus position in the hip of 90° and 100° respectively. In the third case the shortening was caused by re dislocation in the hip joint; the extent of the shortening was not measured in this patient. In the 13 patients

with primarily bilateral dislocations there was no difference in leg length

Mobility Two patients had restricted mobility in the relevant hip joint In one the restriction amounted to a slight reduction in all movements and a 15° flexion contracture In the other patient the restriction consisted in reduced abduction Thus 96 per cent of the treated hip joints showed normal mobility

Situation of femoral head One patient showed re-dislocation of the hip joint while in all the others the femoral head was *in situ* in the acetabulum In other words 98 per cent of the treated hips showed successful reduction of the dislocation

Size of femoral head In 2 cases the femoral head in the treated hip was smaller than that in the unaffected hip In all the others the femoral heads were of equal size in both hips In the 13 patients with bilateral dislocations the size of the femoral head in the right and left hip was assessed in relation to each other in relation to the size of the acetabulum and in relation to the size of femoral heads in normal hips of children of the same age In all 13 patients the size of the femoral head was found to be normal

Structure of the femoral head In 2 cases the bony structure of the femoral head was irregular and in 1 case it could not be assessed because of a greatly reduced size of the head In the 13 patients with bilateral dislocations the bony structure was compared with that in normal hips of children of the same age A normal bony structure was found in 94.5 per cent of the treated hips

Appearance of acetabulum In 1 patient the roof of the acetabulum on the treated side was abnormally steep and dysplastic In all the others the acetabulum was normal Thus 98 per cent of the treated hips showed normal acetabula

Orientation of the upper end of the femur Varus deformity was found in 2 hips corresponding to 4 per cent of the dislocations In these 2 hips the angle between the shaft and neck of the femur was 100° and 90° measured on the anteroposterior views of the hip joints in a position of neutral rotation The possible presence of valgus deformity and anteversion of the upper end of the femur was assessed by means of 2 anteroposterior views one with the hips in a position of neutral rotation, the other with abducted internally rotated hips If the head neck angle exceeded 145° the appearance was taken to represent valgus deformity The degree of anteversion was estimated on the basis of the two projections Valgus deformity was found in 7 hips of 4 patients

Four of these hips had been treated for dislocation while 3 had not been dislocated Thus 8 per cent of the treated dislocations showed valgus deformity Increased anteversion of the upper end of the femur was found in 2 patients with unilateral dislocations These 2 patients also had increased anteversion of the non dislocated hip In one of these patients the anteversion was of the same extent in both hips In the other patient the anteversion was more marked on the side treated for dislocation In 4 per cent of the treated dislocations there was in creased anteversion of the upper end of the femur The anteversion was not however in any case of a degree which indicated derotation os teotomy

Summing up the treatment had given functionally good results in 40 out of 41 patients = 97 5 per cent and in 53 out of 54 dislocations = 98 per cent A radiologically normal result was found in 45 out of 54 treated dislocations In 9 cases there was deformity of the hip skeleton In 3 of these cases the deformity was considerable (2 coxa vara 1 acetabular dysplasia with redislocation) while 6 cases all in patients treated for unilateral dislocations showed mild deformity (coxa valga and anteversion) If the 45 normal hips + the 6 hips showing mild changes of the upper femoral end are considered good there were good radiological results in 51 of the 54 treated hips = 94 5 per cent

COMPLICATIONS

One patient showed when the plaster cast was removed at the end of 13 weeks a slight pressure wound in the left groin The patient had to be admitted for 12 days for treatment of the wound which thereafter healed There were no other therapeutic complications

DISCUSSION

Congenital dislocation of the hip is the most common congenital skeletal malformation in man (*Exner* 1954 *Penners* 1955 *Schlegel* 1961) Its incidence varies geographically and racially (*Shands* 1957 *Schlegel* 1961) In Scandinavia it is 2–3 in 1000 newborns (*von Rosen* 1962 *Vulpius* 1964) The disease is about 6 times more common in girls than in boys (*Hilgenreiner* 1935) and it is more often unilateral than bi lateral (*Muller et al* 1953) All newborn infants should be examined for c d h (*Peltesohn* 1920 *Hilgenreiner* 1935 *Penners* 1955 *Borghlin* 1962 *von Rosen* 1962) and clinical examination is most important In

the presence of Ortolani's phenomenon treatment is indicated. As a rule, primary X-ray examination is unnecessary (*Peltesohn* 1920, *Ortolani* 1951, *Penners* 1955) but in case of clinical doubt special X-ray examinations, e.g. arthrographys, may be considered.

Most authors agree that spontaneous healing of c.d.h. does occur (*Putti* 1929, *Hass* 1951, *Chiari* 1952, *Barlow* 1962, *Vulpius* 1964) but how often is not definitely known. As a non-reduced dislocation will cause great disability in later life, all dislocations should be treated (*von Rosen* 1962), although it is known that some become spontaneously reduced. In newborns the dislocation is rarely fully developed (*Exner* 1954). In most cases there is a question of a state of subluxation or pre-dislocation which may later develop into true dislocation. The previous view that subluxation and dislocation of the hip are two different diseases (*Leveuf* 1947) is no longer accepted (*Ortolani* 1951, *Sommerville* 1953, *Weitnauer* 1955).

The therapeutic results reported in the present paper are on a level with the best ones obtained by others by *early* closed reduction (*Putti* 1933, *Hilgenreiner* 1935, *Bost et al.* 1948, *von Rosen* 1962, *Medbo* 1965). They are better than those obtained by treatment of patients aged 2–3 years (*Bost et al.* 1948, *Schwartz* 1965) which has given good results in a maximum of 65 per cent (*Scott* 1953).

The principle of closed treatment is to fix the reduced dislocation in order thereby to procure the best possibility of a normal development of the hip skeleton (*von Rosen* 1962, 1965). The plaster cast mentioned in the present paper is well suited for the early treatment of c.d.h., as it gives favourable results, the treatment does not traumatize the hip joints, it can be carried out on an out-patient basis, it does not cause the patients discomfort, and the patients are easy to mind. Other forms of early closed treatment, in principle the same as the present one, have given similar good results, and the therapeutic results are comparable, the follow-up period being the same as in the present series (*Putti* 1933, *Bost et al.* 1948, *von Rosen* 1962, *Medbo* 1965).

SUMMARY

The results of early closed treatment of simple congenital dislocation of the hip are submitted. During a period of 8½ years 59 patients with 81 dislocations have been treated in the Orthopaedic Hospital, Aarhus, Denmark. 41 patients with 51 dislocations were re-examined after an average follow-up period of 4 years 8 months. The results were assessed

clinically and radiologically Functionally good results were found in 97 5 per cent of the followed patients and in 98 per cent of the followed dislocations The radiological results were good in 94 5 per cent of the followed dislocations In one patient the result was poor clinically as well as radiogically It is pointed out that early diagnosis and treatment are of decisive prognostic importance and that all newborn infants should be examined for congenital dislocation of the hip For treatment the author recommends a hip plaster cast fixing both hip joints in the Lorenz I position In the great majority of cases a treatment period of 3 months is sufficient

RESUME

Les resultats du traitement ferme precoce de la luxation congenitale simple de la hanche sont exposes A l Hopital Orthopedique d Aarhus il a eté mis en traitement dans l espace de 8 ans et demi 59 malades avec 81 luxations 41 malades avec 54 luxations ont été reexamines au bout d une periode moyenne d observation de 4 ans 8/12 Les resultats sont apprecies en partant d un point de vue clinique et radiologique On a trouve de bons resultats fonctionnels chez 97 5 pour cent des malades et dans 98 pour cent des luxations reexaminees Les resultats radiologiques etaient bons dans 94 5 pour cent des luxations reexaminees Chez un malade le resultat etait mauvais aussi bien d un point de vue clinique que radiologique Il est souligne qu un diagnostic et un traitement precoces sont d une importance decisive pour le pronostic de la maladie et qu il convient d examiner tous les nouveau nes pour constater une luxation congenitale eventuelle Comme traitement il est recommande un bandage de platre qui fixe les deux articulations de la hanche dans la position Lorenz I Le port du bandage pendant trois mois suffira dans la plupart des cas

ZUSAMMENFASSUNG

Die Ergebnisse einer fruhzeitigen geschlossenen Behandlung der einfachen angeborenen Huftverrenkung werden vorgelegt Am Orthopadischen Krankenhaus in Aarhus wurden im Verlaufe von 8½ Jahren 59 Patienten mit 81 Luxationen behandelt 41 Patienten mit 54 Luxationen wurden mit einer durchschnittlichen Beobachtungszeit von 4 8/12 Jahren nachuntersucht Die Ergebnisse wurden klinisch und röntgenologisch beurteilt Funktionell gute Ergebnisse wurden bei 97,5 Pro

zent der nachuntersuchten Patienten und in 98 Prozent der nachuntersuchten Luxationen gefunden. Die röntgenologischen Ergebnisse waren gut bei 94,5 Prozent der nachuntersuchten Luxationen. Bei einem Patienten war das Ergebnis sowohl klinisch als auch röntgenologisch schlecht. Man hebt hervor, dass frühzeitige Diagnose und Behandlung von ausschlaggebender Bedeutung für die Prognose des Leidens ist, und dass *alle Neugeborenen auf angeborene Hüftverrenkung untersucht werden sollten*. Als Behandlung empfiehlt man eine Hüftgipsbandage, die beide Hüften in Lorenz I Stellung fixiert. Bandagierung für 3 Monate wird in weitaus den meisten Fällen zureichend sein.

REFERENCES

Barlow, T. G. (1962): Early Diagnosis and Treatment of Congenital Dislocation of the Hip. *J. Bone Jt. Surg.* 44 B: 292.

Borghlin, N. E. (1962): Medfødt hofteluksation. *Tidsskrift for Jordemødre* 72: 123.

Bost et al. (1948): The results of Treatment of Congenital Dislocation of the Hip in Infancy. *J. Bone Jt. Surg.* 30 A: 454.

Chiari, K. (1952): Ergebnisse der Frühestbehandlung der angeborenen Hüftgelenkverrenkung. *Arch. orthop. Unfall-Chir.* 45: 644.

Exner, C. (1954): Probleme der modernen Hüftluxationsbehandlung. *Deutsche Med. Wschrft.* 79: 1001.

Hass, J. (1951): Congenital Dislocation of the Hip. Charles C. Thomas, Illinois.

Hilgenreiner, H. (1935): 10 Jahre Abduktionsscheine und Frühbehandlung der angeborenen Hüftverrenkung. *Zeitschrift orthop. Chir.* 63: 344.

Leveuf, J. (1947): Primary Congenital Subluxation of the Hip. J. Bone Jt. Surg. 29: 149.

Medbø, I. (1961): Follow up Study of Hip Joint Dysplasia Treated from the Newborn Stage. *Acta orthop. scand.* 31: 338.

Muller, G. M. & Seddon, H. J. (1953): Late Results of Treatment of Congenital Dislocation of the Hip. *J. Bone Jt. Surg.* 35 B: 342.

Ortolani, M. (1951): Frühdiagnose und Frühbehandlung der angeborenen Hüftgelenksverrenkung. *Kinderärztliche Praxis* 19: 404.

Peltesohn, S. (1930): Über Erkennung und Behandlung der angeborenen Hüftgelenksverrenkung beim Säugling. *Med. Klinik* 26: 442.

Penners, R. (1955): Frühdiagnose und Sofortbehandlung der angeborenen Hüftluxation. *Arch. orthop. Unfall-Chir.* 47: 391.

Ponseti, I. V. (1961): How should Congenital Dislocated Hip be Treated. *Mod. Med.* 29: 198.

Putti, V. (1929): Early *Treatment of Congenital Dislocation of the Hip. J. Bone Jt. Surg.* 11: 798.

Putti, V. (1933): Early Treatment of Congenital Dislocation of the Hip. *J. Bone Jt. Surg.* 15: 16.

Schlegel, K. F. (1961): Die angeborene Hüftluxation. Handbuch Orthop. von Hohmann, G., Hackenbroch, M. & Lindemann, K. 4. Georg Thieme Verlag, Stuttgart.

Schwartz, D. R. (1965): Acetabular Development after Reduction of Congenital Dislocation of the Hip. *J. Bone Jt. Surg.* 47 A: 705.

Scott J C (1953) Frame Reduction in Congenital Dislocation of the Hip *J Bone Jt Surg* 35 B 372

Shands A R. (1957) Congenital Dislocation of the Hip Handbook of Orthopaedic Surg Fifth Edition The C V Mosby Company St Louis

Somerville E W (1953) Development of Congenital Dislocation of the Hip *J Bone Jt Surg* 35 B 568

Von Haberler G (1944) Neue Erkenntnisse der angeborenen Huftgelenksverrenkung und ihre Behandlung *Zeitschrift Orthop* 75 38

Von Rosen S (1957) Early Diagnosis and Treatment of Congenital Dislocation of the Hip *Acta orthop scand* 26 136

Von Rosen S (1962) Diagnosis and Treatment of Congenital Dislocation of the Hip *J Bone Jt Surg* 44 B 284

Von Rosen S (1962) Die Diagnose und Behandlung der kongenitalen Huftgelenks luxation bei Neugeborenen Verhandlungen der deutschen orthopadischen Gesellschaft 50 Kongress 430–437

Von Rosen S (1965) Weitere Erfahrungen in der Behandlung der Huftgelenksverrenkung bei Neugeborenen *Zeitschrift Orthop* 99 18

Vulpius J (1964) Tidlig diagnose af luxatio coxae congenita *Nord Med* 17 493

Weitnauer H. (1955) Sind Subluxation grundsatzlich verschiedene Fehlentwicklungen des Huftgelenkes? *Arch orthop Unfall Chir* 47 429

Acta orthop Scandinav 40 62–71 1969

From the Orthopaedic Hospital Aarhus Denmark
(Head Professor Eivind Thomasen M D)

ANTEVERSION DEFORMITY AND DEROTATION OSTEOTOMY IN CONGENITAL DISLOCATION OF THE HIP

By

IB CHRISTENSEN

Received 14 1 68

An anteversion deformity in congenital dislocation of the hip means a disproportion in direction between the neck and head of the femur on the one hand and the acetabulum on the other so that the head does not reach the bottom of the socket in the normal position, but assumes an eccentric position

The anteversion deformity is due not only to the anterior direction of the neck head but also to frontal or ventral rotation of the acetabulum Both factors vary considerably without any interdependence (*Laurent* 1953)

Sandifort Jr (1836) appears to have been the first to point out an increased anteversion of the femoral neck in infants having congenital dislocation of the hip

The extent of this anteversion has been determined *inter alios* by *Putti* (1937) who found it to range from 33 –84 in autopsies in children aged 1–6 years with congenital dislocation of the hip Measurements during open reduction by *Farrell & Howorth* (1935) showed 63 and by *Laurent* (1953) 10 –80 average 37 in patients up to 3 years of age

Radiological determinations of the anteversion of the femoral neck in children with congenital dislocation of the hip have been in the focus of interest ever since the studies of *Drehmann* (1908) Such methods have been described by *inter alios Dunlap Shands Hollister & Streit* (1953) *Ryder & Crane* (1953) and *Billing* (1954)

The variations in the frontal inclination of the acetabulum have been studied by *Putti* (1937) in autopsies on patients with congenital dislo



Figure 1a Arthrogram taken when the cast was removed 3 months after the reduction In spite of a position of abduction internal rotation there is a 4 mm contrast pool on the acetabular floor indicating severe anteversion deformity Derotation osteotomy was not done because of progressive muscular dystrophy



Figure 1b 18 months after cast was removed Outward displacement of the head neck incipient bony filling in of the bottom of the socket (arrow) and obliteration of the lateral limb of the U figure



Figure 1c 7½ years after removal of the cast Massive bony filling in of the floor of the socket with flattening of the acetabulum as a result of severe subluxation Acetabular roof fairly well developed

Figures 1a 1b and 1c Bony filling in of the acetabular floor in anteversion deformity Complete dislocation with isthmus treated, after unsatisfactory closed reduction at the end of the 2nd year of life

cation of the hip in the first 5–6 years of life He found the anteversion to range from 35° to 54 In measurements during open reductions on children aged 1–3 years *Laurent* (1953) found the variations to be from 15 –55 and demonstrated that the anteversion of the neck and the ventral rotation of the acetabulum varied independently of each other

Since the two factors which determine the disproportion between the articulation of the femoral head with the acetabulum in congenital dislocation of the hip show the same wide range it serves no practical purpose to determine one of these factors accurately in degrees by means of complicated X ray projections and mathematical calculations —*at least while there is no radiographic method for assessing the anteversion of the acetabulum* On the other hand the result of the interplay of these two factors may be assessed arthrographically with contrast medium in the joint

The first radiological sign of a deficient adjustment of the femoral head after closed reduction followed by plaster casts has been completed is slight outward displacement with recurrence of the ante*version configuration and a widened joint space At times however* the latter may prove merely apparent due to a reduced size of the ossification centre Somewhat later there will be signs of incipient bone filling in the acetabular floor with widening or obliteration of the U figure If the anteversion deformity remains uncorrected this filling with bone will continue and become an important cause of the so called shallow acetabulum (Figures 1 b and c)

ARTHROGRAPHIC ASSESSMENT OF THE ANTEVERSION DEFORMITY

An eccentric situation of the femoral head in the acetabulum due to a disproportion in their directions so that the head does not contact the bottom of the socket shows in the arthrogram a sickle shaped pool of contrast medium when the exposure has been made with the hip extended and in a neutral position (Figure 2 a)

The pool will be diminished and may even completely disappear on films taken in internal rotation (Figure 2 b) The degree of internal rotation required to make the sickle shaped contrast pool disappear gives a direct measure of the anteversion deformity and thus of the number of degrees required in derotation If mild subluxation co exists the arthrogram in internal rotation also shows the head and

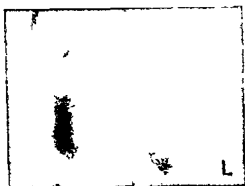


Fig 2 a



Fig 2 b

Figures 2a and 2b Arthrogram showing typical anteversion configuration B 63 433 Arthrogram (2a) in slight abduction and neutral rotation showing a pool of contrast medium about 5 mm wide between the femoral head and acetabulum. On internal rotation the pool disappears (2b) The pool is due to anteversion deformity which ought to be corrected

glenoidal labrum to be lower in relation to the Y line than on a film taken in the normal anatomical position

Therefore arthrographic check up following closed reduction should not be done until mobility in the hip joint has been re established to the extent that the hip can be placed without force in the positions necessary for these projections

There is arthrographic indication for derotation osteotomy when a sickle shaped contrast pool exceeding 2–3 mm in width at the acetabular floor disappears entirely or partially upon internal rotation or when the glenoidal labrum shows elevation diminished upon internal rotation

No other diagnostic method is of the same practical value in assessing the question of incongruence due to anteversion deformity and thus in deciding the indications for derotation osteotomy

DEROTATION OSTEOTOMY

Schede's name was identified with the first derotation osteotomy (*Pe tersen* 1899) but this is not correct *Schede* was an ardent adherent of correcting the anteversion deformity it is true but it was the Danish surgeon *Tscherning* (1894) who performed the first operation and during the same stage open reduction and subtrochanteric derotation osteotomy on a 12 year old girl with unilateral dislocation of the hip In this case the direction of the femoral neck was parallel to the long axis of the foot

In *Lorenz* (1895) opinion the technical difficulties in fixing the proximal fragment were so great that he did not only advise against derotation osteotomy but also felt that open reduction was contra indicated in the presence of severe anteversion deformity

Leveuf, in 1941 believed that the anteversion factor caused a number of secondary subluxations but in 1946 he felt that this was not correct (*Leveuf & Bertrand* 1946) *Bertrand & Guias* (1955) performed derotation on only 17 out of 551 treated cases

Platou (1953) demonstrated that dislocated hips showing anteversion of 30° or more of the femoral neck at follow up were subject to sub luxation or re dislocation in 87 per cent of the cases He convincingly demonstrated the value of derotation osteotomy which was done if the anteversion deformity exceeded 35

This is not however, *per se* any proof that the anteversion deformity induces dislocation or subluxation But when considering also the in creased stability and possible abolition of subluxation in internal rota tion it seems justified to attribute to the anteversion deformity a cen tral role in the mechanism of dislocation

It cannot be the true cause of congenital dislocation of the hip be cause as mentioned below the anteversion deformity sometimes recurs after sufficient derotation This indicates that the anteversion de formity is the result of deeper lying unknown forces in the dislocated hip

Francillon (1955) corrects anteversion when it exceeds 30°—which it did in 75 per cent of his open and 50 per cent of his closed reductions

Sommerville (1955) consistently does derotation on all complete dislocations although he does admit that in certain cases the ante version deformity will regress spontaneously As a motive for this attitude he stresses that derotation increases stability that the period

in plaster is shortened and mobilization of the hip may be started earlier

In the present author's experience too an anteversion deformity may spontaneously regress after reduction However while there is no means of predicting in which cases this will occur derotation osteotomy should be carried out as soon as it has been demonstrated and before bone filling of the acetabular floor starts In that event acetabuloplasty is very seldom *indicated* as also *pointed out by Desorgher* (1955) and *Francillon* (1955)

At the Orthopaedic Hospital, Aarhus derotation osteotomy is performed in all open reductions on hips showing an anteversion exceeding 30 and if stability is poor also less than 30

After closed reduction it is endeavoured to decide within one year whether correction is to be done This practice is on the whole in keeping with *Platou* (1953) *Francillon* (1955) *Sommerville* (1955), and *Muller* (1957)

PREVIOUS METHODS

Zahradnicek's (1934) osteotomy at the junction of the greater trochanter and femoral neck is wedge shaped with the object of correcting the anteversion of the head neck as well as the valgus deformity This procedure must be considered to jeopardize the vascularization of the head and neck

Intertrochanteric osteotomy is theoretically the most correct procedure partly because the lesser trochanter with the psoas muscle attached is included in the derotation—so that the externally rotating effect of this muscle will be more or less neutralized—and partly because this method is best suited for simultaneous correction of the valgus deformity

Bernbeck (1954) has advocated a low and oblique intertrochanteric osteotomy which corrects both factors and *Francillon* (1950) an intertrochanteric transverse osteotomy in which the fixation is maintained by a compression apparatus which also serves to correct the valgus deformity *Francillon* has performed about 100 intertrochanteric osteotomies without having observed structural changes in the femoral head, which might perhaps be feared *a priori* and which some authors consider the main objection to this form of osteotomy

Subtrochanteric osteotomy has been recommended by *Ponseti* (1944) *Platou* (1953) and *Somerville* (1953) This method is considerably less suited than the intertrochanteric method for correcting the valgus deformity However it possesses the advantage of entailing less risk of vascular disturbances, the internal fixation material is farther from the growth zones and it is technically easier

Diaphyseal osteotomy is used by *Langenskiold* (1953) and his assistant *Laurent* (1953) combined with transposition of the psoas tendon to the lateral aspect of the femur This tendon transposition was described independently by *Rohleder* (1947) and *Langenskiold* (1953) It is a serious objection to this method that bone healing is slower and that it is unsuited to be done in the same stage as open reduction.

PRESENT METHOD

The derotation osteotomies at the Orthopaedic Hospital Aarhus are subtrochanteric, using a wire saw just distal to the lesser trochanter A short vitallium plate with 4 holes is fixed distally to the bone, so that the wire saw is on a level with the middle of the plate. After a Steinmann pin has been driven into the greater trochanter from the lateral side to act as a temporary guide pin and goniometer the bone is sawn through and the proximal fragment rotated inward into a position of anteversion of 10–15° The plate is fixed with two screws to the greater trochanter and the hip is kept in a plaster cast for 6 weeks. As a rule the plate is not removed.

MATERIAL

A total of 147 patients under 5 years of age representing 201 dislocated hips, were treated in the Orthopaedic Hospital, Aarhus during the period 1947–1955 The therapeutic principles were on the lines advocated by *Leveuf* *i e* arthrographic determination of the type of dislocation and checking of the quality of closed reduction before applying the plaster cast. If reduction was unsatisfactory arthrographically open reduction was done without any preceding attempt at bandaging The extent and development of the anteversion deformity were followed and if necessary correction by derotation osteotomy was done

Out of these patients 145 representing 197 hips are alive, and all have been seen in a follow up study after 4–12 years.

Correction of anteversion deformity was done by subtrochanteric derotation osteotomy in 39 of the 201 cases treated according to the principles of *Leveuf* (19 per cent)

Derotation was used as a corrective procedure in 29 cases in the same stage as the open reduction in 11 cases and as a palliative procedure in 10

In 2 instances the derotation osteotomy had to be repeated. In one of these cases the derotation had primarily been insufficient *viz* 50° of a 90° anteversion and in the other case the anteversion deformity had recurred. This latter case is interesting seeing that in the primary operation the derotation amounted to 50° of an 80° anteversion Later an additional 40° derotation was done At follow up two years after the latter correction there was again considerable anteversion deformity

In another three cases the anteversion deformity had recurred, so that in 4 out of the 39 cases (10 per cent) there were recurrences

The real need for operative correction of the anteversion deformity has not been fulfilled by the 39 derotation osteotomies The minimum requirement may be estimated by investigating how many hips exhibited at follow up the sequelae of an uncorrected anteversion deformity in the form of bony filling of the bottom of the socket or major or minor obliteration of the U figure or exhibited typical anteversion configuration of the head neck. Such sequelae were found in 35 cases.

Thus 74 (39 + 35) of the 201 cases must be said to have required derotation osteotomy *i e* a minimum requirement in the present series of almost 40 per cent. In practice, a larger percentage is required since it is not possible to decide beforehand in which hips the deformity is going to be spontaneously corrected and in which cases active interference is needed.

SUMMARY

The author describes the anteversion deformity in congenital dislo cation of the hip stressing the importance of arthrography using con trast medium in deciding the indication for correcting derotation osteotomy

Among 201 cases of congenital dislocation of the hip treated prima rily during the first 5 years of life 39 had derotation osteotomy After follow up periods which always exceeded 4 years the non-derotated cases were seen This disclosed in another 35 definite radiological sequelae of uncorrected anteversion deformity

Derotation osteotomy should be done in the presence of anteversion of 30 and over and—if open reduction reveals instability—also if it is less than 30

RESUME

L auteur décrit la deformite d anteversion dans la dislocation conge-nitale de la hanche soulignant l importance de l arthrographie utilisant on agent de contraste poor decider de l indication d une osteotomie de correction de la dérotation

Parmi 201 cas de dislocation congenitale de la hanche traites pri mairement durant les cinq premieres annees de la vie 39 avaient subi l osteotomie de derotation Apres une periode d observation qui a tou jours depasse 4 ans les cas de non derotation ont ete reexamines On constata dans 35 cas des sequelles radiologiques certaines d une de formite d anteversion non corrigee

L osteotomie de derotation doit etre pratiquee en presence d une anteversion de 30 et plus et—si la reduction ouverte revele de l insta bilite – également si elle est inferieure a 30

ZUSAMMENFASSUNG

Der Verfasser beschreibt die Anteversionsdeformitet bei angeborener Hüftverrenkung und betont die Wichtigkeit der Arthrographie mit Kontrastmittel um die Anzeige für die korrigierende Derotationsosteo tomie zu entscheiden

Von 201 Fallen von angeborener Huftverrenkung die ursprünglich wahrend der ersten 5 Lebensjahre behandelt worden waren hatten 39 eine Derotationsosteotomie Nach Beobachtugszeitspannen die immer 4 Jahre uberschritten wurden die nicht derotierten Falle gesehen

Dies zeigte bei noch weiteren 35 Fällen röntgenologisch Folgezustände einer nicht korrigierten Anteversionsdeformität auf

Derotationsosteotomie sollte beim Vorhandensein einer Anteversion von 30° und mehr und – wenn eine offene Einrenkung Instabilität zeigt – auch bei weniger als 30 Anteversionwinkel ausgeführt werden

REFERENCES

1 Bernbeck Rupprecht (1954) Kinderorthopadie Georg Thieme Stuttgart P XII + 234

2 Bertrand P & Cuias H (1955) Resultats du traitement de la luxations con genitale de la hanche chez le jeune enfant. *Rev Orthop* 41 56–72

3 Billing L (1954) Roentgen Examination of the Proximal Femur End in Children and Adolescents *Acta radiol* Suppl 110 Goteborg P 80

4 Desorgher (1955) XXIX Reunion Annuelle de la Societe Francaise d Orthopedie et de Traumatologie 1954 *Rev Orthop* 41 119

5 Drehmann G (1908) Weitere Beitrage zur unblutigen Behandlung der angebore nen Huftgelenksverrenl ung *Z Orthop* 20 61–126

6 Dunlap K et al (1953) New Method for Determination of Torsion of the Femur *J Bone Jt Surg* 35 A 289–311

7 Farrell B P & Howorth M B (1935) Open Reduction in Congenital Dislocation of the Hip *J Bone Jt Surg* 17 35–42

8 Francillon R. (1955) XXIX Reunion Annuelle de la Socitete Orthopedie et de la Traumatology 1954 *Rev Orthop* 41 122–123

9 Langenskiold F (1953) On the Transposition of the Ileopsoas Muscle in Opera tive Reduction of Congenital Hip Dislocation *Acta orthop scand* 22 295–299

10 Laurent L. E (1953) Congenital Dislocation of the Hip *Acta chir scand* Suppl. 179

11 Leveuf J (1941) Etude des resultats eloignes de la reduction non sanglante des luxatons congenitales de la hanche *J Chir* 57 11–39

12 Leveuf J & Bertrand P (1946) Luxations et subluxations congenitales de la hanche Dion Paris

13 Lorenz A (1895) Ueber die operative Behandlung der Huftverrenl ung *Verh dtsch Ges Chir* 24 74–75

14 Muller M E (1957) Die Huftnahen Femurosteotomien Georg Thieme Stuttgart, m p *XII + 184*

15 Petersen H (1899) Beitrag zur unblutige Behandlung der congenitalen Huft verrenkungen *Dtsch Z Chir* 50 534–598

16 *Platou E (1953) Rotation Osteotomy in the Treatment of Congenital Disloca* tion of the Hip *J Bone Jt Surg* 35 A 48–54

17 Ponseti I (1944) Causes of Failures in the Treatment of Congenital Dislocation of the Hip *J Bone Jt Surg* 26 775–792

18 Putti V (1937) Die Anatomie der angeborenen Huftverrenkung Ferd. Enke Stuttgart.

19 Rager Wilhelm (1902) Luxatio coxae congenita. Gyldendalske Boghandels for lag Copenhagen 370

20 Rohleder O (1948) Das Torsions Problem der Luxatio Coxae und seine klinische Behandlung *Z Orthop* 78 277
21 Ryder C T & Crane L (1953) Measuring Femoral Anteversion The Problem and a Method *J Bone Jt Surg* 35 A 321-328
22 Sandifort (1836) cit. Rager
23 Somerville E W (1953) Development of Congenital Dislocation of the Hip *J Bone Jt Surg* 35 B 568-577
24 Somerville E W (1955) Reunion Annuelle de la Societe Francaise D Orthoperie et de la Traumatologie 1954 *Rev Orthop* 41 134-140
25 Tscherning (1894) *Bibl Læger* 197-203
26 Zahradnicek J (1934) Beitrag zur Reposition der Hohen angeborenen Huft verrenkungen *Arch klin Chir* 180 353-363

Acta orthop Scandinav 40 72–78 1969

From the Hospital for Special Surgery affiliated with the New York Hospital – Cornell Medical Center New York New York and the Department of Orthopaedic Surgery Malmo General Hospital University of Lund Malmo

THE INFLUENCE ON BREAKING FORCE OF OSTEOPOROSIS FOLLOWING FRACTURE OF THE TIBIAL SHAFT IN RATS

By

BO E R NILSSON & ROBERT E SMITH

Received 1 ix 67

INTRODUCTION

Loss of mineral in a fractured bone and in neighboring bones is a frequently encountered phenomenon In cases of tibial shaft fracture in humans *Nilsson* (1966) found that there was a loss of about 25 per cent in the cancellous bone at the distal end of the adjacent femur

In rats similar changes have been shown to occur by *Bauer* (1954) and by *Bohr* (1955)

It is the object of the present work to study the osteoporosis which appears in the proximal end of the rat tibia following fracture of the tibial shaft The bones are evaluated in terms of ash weight loss and of decrease in resistance to compressional fracture

MATERIALS AND METHODS

Twenty female Wistar rats were used The weight of the rats was 252 ± 14 grams (range 223–271) This weight was chosen to minimize the influence of rat growth during the period of the experiment and no significant growth was observed during this time.

The left tibial shaft of each rat was manually fractured under anaesthesia The right tibias were to serve as controls Four weeks later the rats were sacrificed and both tibias were removed and cleaned The proximal end of each tibia was then cut away and the rest of the bone discarded In each case the end retained accounted for exactly one fifth of the original bone length Since the fracture area was located near the middle of the shaft it was always excluded from the test specimen

The compression tests were carried out on a Riehle 5000 kg Materials Testing Machine operated on its lowest scale (0 ?50 kg) and calibrated to an accuracy of 0 5 per cent This is a standard industrial testing instrument It has a motor driven head which presses the specimens down against a scale platform. A system of levers transmits the platform displacement to an indicator dial which reads in kilograms of force

To ensure that the specimen was held in the proper position during the test is was mounted in the way shown in Figure 1 The force from the testing machine was transmitted to the sample through two plastic disks which were free to slide in a plastic sleeve It was necessary to provide two flat parallel surfaces on the bone so that the force from the disks should be transmitted evenly to the ends of the sample and directly along its longitudinal axis The condylar end of each specimen was therefore flattened slightly with a fine grinding wheel and then the cut end of the shaft was carefully ground parallel with it. To ensure that the cut end of the shaft should not fracture before the epiphyseal end a fine wire was bound around the shaft to reinforce it The breaking force of a bone varies with its degree of hydration (*Evans & Lebow* 1952) Prior to testing the samples were hydrated in saline solution under negative pressure for one hour This assured a thorough and constant water content

Each sample was then tested under compression and the initial failure point was recorded. The initial failure point represents the highest resistance the specimen could offer to compression. If the test was carried beyond this point the resisting force decreased to a lower range of values as the bone gradually collapsed When the test was halted at initial failure no definite fracture was discernible by eye Just beyond this point however the bone could be clearly seen to fracture at a point just below the epiphyseal line After the breaking force determination each sample was ashed for 48 hours at 550 C, and the ash weight determined

RESULTS

The average ash weight and breaking force of the injured and control sides are presented in Table 1 The ash weight was found to be significantly less on the injured side ($P<0.01$) The breaking force of the injured side was also found to be significantly less than the uninjured side ($P<0.001$) The percentage loss in breaking force was significantly higher than the percentage loss in ash weight ($P<0.001$) Although ash weight and breaking force form a regression when samples from both injured and control sides are included there was no such regression within each group considered separately (Figure 2)

In Figure 3 the loss in ash weigh is plotted against the ash weight of the normal (right side) tibia sample ($P<0.01$) Figure 4 is an analogous plot of the decrease in breaking force versus the breaking force of the normal side ($P<0.001$)

The weight of the animals was not related to the ash weight of the

Table 1 Ash weight and breaking force Average ± SD

	Ash weight (mg)	Breaking force (kg)
Normal side	62.2 ± 9.7	19.1 ± 4.5
Fracture side	52.1 ± 7.8	10.3 ± 2.8
Per cent Loss	15.4 ± 10.8	44.4 ± 14.3

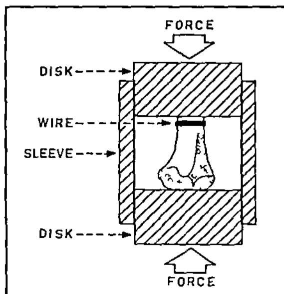


Figure 1 Bone sample mounted for testing (Cutaway view)

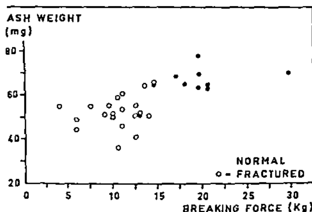


Figure 2 Ash weight of tibia samples versus breaking force

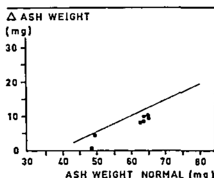


Figure 3 Ash weight difference between samples from the normal and injured sides versus ash weight of the normal side

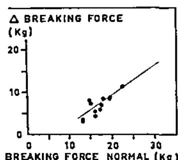


Figure 4 Breaking force difference between samples from the normal and injured sides versus breaking force of the normal side

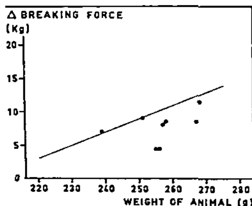


Figure 5 Difference in breaking force versus weight of animal

uninjured side or to the loss of ash weight nor was it related to the breaking load of the uninjured side The loss of breaking force how ever was significantly ($P<0\ 001$) correlated to the weight of the ani mals Extrapolation of the regression in Figure 5 to zero seems to indicate that below a body weight of 200 grams no change in the break ing load occurs after fracture Additional experiments including a wider range of animal weights will be necessary before any conclusions can be made about this finding

DISCUSSION

The loss in ash weight observed in the present experiment confirms the presence of post traumatic osteoporosis in the experimental limbs This osteoporosis is associated with a relatively large fall in resistance to fracture Since the specimens were not of uniform diameter and since each was largely cancellous bone no estimation of stress (breaking force per unit cross section) could be made *Nilsson & Saville* (1967) demonstrated a retardation of growth of the skeleton in fractured legs of growing rats In the present study no significant growth could be demonstrated in the rats It must therefore be assumed that the samples from the two sides were of equal size Thus the observed breaking force difference must be attributed to a loss in bone quality

Reports in the literature vary regarding the possibility of establishing a direct relationship between mineral content and bone strength In studies on intact human femur *Vose & Kubala* (1959) were able to demonstrate a relation between breaking stress and mineral content where mineral content was measured by an X ray absorption method On the other hand *Mehel & Miller* (1966) investigating age changes observed a significant fall in the breaking stress of uniformly machined human tibia samples but were unable to detect any change in specific ash weight

In studies on rats *Saville & Smith* (1966) found that femur density calcium per unit volume breaking force and breaking stress are linear functions of body weight and therefore of each other (*Saville & Smith* 1966 *Smith & Saville* 1966) In bipedal animals where the weight bear ing of the femora was increased it was found that breaking force and stress had risen to higher values than could be accounted for on the basis of a density increase alone (density expressed either as weight per unit volume or calcium per unit volume)

In studying the effects of a rachitogenic diet on rats, *deWeir et al*

(1949) found a relationship between the breaking stress and ash weight of the femur of animals from various diet groups Within each diet group no such relationship could be found

The findings of the present work are similar in that a relation between breaking force and ash weight is found only when samples from both the injured and the control side are included The discrepancy between the ash weight and breaking force losses indicates that factors other than loss in mass alone are responsible for the deterioration in the mechanical quality of the bone

In the graphs (Figures 3 and 4) in which the losses in ash weight and breaking force are plotted respectively against the normal side values for each rat both regressions have significant intercepts Thus when the loss in ash weight and breaking force between the normal and fracture side is zero the bone still has a certain ash weight and breaking force This seems to indicate that a certain fraction of the bone sample tested presumably the cortical bone to a lesser degree the participates in the process of resorption

SUMMARY

Tibial shaft fractures in rats were found to cause a loss of bone in the proximal end of the tibia This loss was found to be associated with a loss of resistance to longitudinal compression of the proximal end of the bone This change in quality was found to be greater than could be accounted for by loss of mass only

RÉSUMÉ

On a découvert que les fractures du corps du tibia chez les rats causent une perte d'os dans la partie proximale du tibia Celle ci doit être associée à une diminution de la résistance de la partie proximale de l'os à la compression longitudinale Cette modification de la qualité osseuse est en réalité plus importante qu'on aurait pu s'y attendre compte tenu de la seule perte de masse

ZUSAMMENFASSUNG

Es wurde gefunden dass Tibiaschaftbrüche bei Ratten einen Knochenverlust am proximalen Ende der Tibia hervorriefen Dieser Verlust war mit einem Widerstandsverlust gegen longitudinale Kompression des

proximalen Endes des Knochens verbunden Diese Veranderung in der Beschaffenheit war grosser als man aus dem Verlust der Masse allein erwarten konnte

REFERENCES

Bauer G C H (1954) Rate of bone salt formation in a healing fracture determined in rats by means of radiocalcium *Acta orthop scand* 23 169–191

Bohr H H (1959) Studies on fracture healing *J Bone Jt Surg* 37 A 327–337

Evans F G & Lebow M (1952) The strength of human compact bone as revealed by engineering technics *Amer J Surg* 83 326–331

Melick R A & Miller D R (1966) Variations of tensile strength of human cortical bone with age *Clin Sci* 30 243–248

Nilsson B E R (1966) Post traumatic osteopenia A quantitative study of the bone mineral mass in the femur following fracture of the tibia in man using Americium 241 as a photon source *Acta orthop scand* Suppl 37

Nilsson B E R & Saville P D (1968) Influence of growth and trauma on bone mass and mineral turnover in rats *Acta orthop scand* 39 273–280

Saville P D & Smith R E (1966) Bone density breaking force and leg muscle mass as functions of body weight in bipedal rats *Amer J Physiol Anthropol* 25 (in press)

Smith R E & Saville P D (1966) Bone breaking stress as a function of weight bearing in bipedal rats *Amer J Physiol Anthropol* (in press)

deWeir J B Bell G H & Chambers J W (1949) The strength and elasticity of bones in rats on a rachitogenic diet *J Bone Jt Surg* 31 B 444–451

Vose G P & Kubala A L (1959) Bone strength—its relation to X ray determined ash content *Hum Biol* 31 261–270

Acta orthop Scandinav 40 79-85 1969

From the Departments of Orthopaedics (Head O Lindahl) Clinical Physiology (Head H Linderholm) and Diagnostic Radiology (Head G F Saltzman) the University Hospital Umeå Sweden

KNEE EXTENSION

Measurement of the Isometric Force in Different Positions of the Knee Joint

By

O Lindahl A Movin & I Ringqvist

Received 30.xi 67

On the basis of measurements made in radiographs with the knee in different positions *Lindahl & Movin* (6) calculated the relationship between the various forces acting in the joint on active extension against resistance Particular attention was devoted to the relation between the force exerted by the quadriceps during extension and that developed peripherally on the lower leg It was found that with the leverage conditions obtaining in the knee joint the force exerted by the quadriceps in a flexed position (160–90) was about 7 times greater than that produced on the lower leg at a point 30 cm distal to the joint In the position of extension the leverage was less favourable the force on the lower leg being only one ninth or occasionally one twenty fifth of that exerted by the quadriceps

It was considered of interest to assess the absolute force exerted by the quadriceps irrespective of the leverage conditions this was done by measuring the maximum isometric force developed normally on extension of the knee

MATERIAL AND METHODS

The study was performed on twelve 20 48 year old, apparently healthy men most of them belonging to the personnel of this hospital.

The voluntary maximum isometric muscular force was recorded with a Darcus dynamometer as modified by *Bonde Petersen* (1)

The subject was placed on a table with the knee joint over the edge of the latter and the trunk immobilized by a strap over the pelvis The dynamometer was placed so that its axis of rotation coincided as closely as possible with the joint space. The

knee was extended against a leather strap the middle of which was 30 cm from the axis of the dynamometer and the joint space The force was recorded for angles of 90 105 120 135 150 165 between the table and the lower leg These values approximately denote the angle between the median contours of the thigh and lower leg A source of error (too low values) is introduced by the compression of the soft tissues of the thigh and the flexibility of the table and apparatus particularly for the large angles To obtain a more accurate impression of the knee angle during the last 30 of extension in this range simultaneously with each measurement of the force a radiograph was taken of the knee joint and a series of measurements and determinations of the angle were made between 150 and extension As the muscular force is not great enough to produce full extension against the weight of the leg the maximum passive extension was found in the radiographs this was done by a technique described by *Lindahl & Movin* (7) For all the angles except 90 the weight of the apparatus and the lower leg exerted a force at the point of measurement 30 cm below the knee joint and this was added to the values recorded on the dynamometer The weight of the lower leg and foot and the position of the centre of gravity were determined from values reported by *Demster* (3) and the measured length of the lower leg for the individual subjects

RESULTS

The means for the force of extension measured as the moment in the range 90–135 for 6 subjects are given in Figure 1 The largest moment 2300 kgf cm was developed at 120 The difference in the moments for flexion from 120 to 105 is not significant but from 90 to 120 there

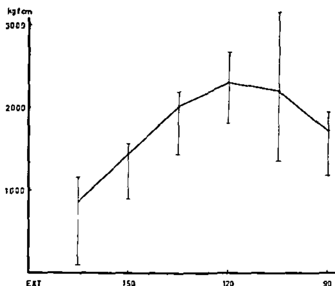


Figure 1 The relationship between the angle of the knee joint and the maximum moment for 6 healthy subjects means and ranges

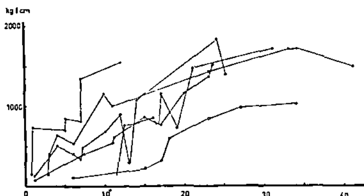


Figure 2 The relationship between the angle of the knee joint measured as flexion from full passive extension and the maximum moment for each of 6 subjects

was an almost significant reduction (0 02>P>0 01) In extension there was a gradual reduction in the moment and the difference between 120 and 135 was almost significant (0 02>P>0 01) As there was a fairly large angular distance between the reference points (15) and only 6 subjects were used it is not possible to ascertain the exact angle for which the force was a maximum Figure 2 shows the values for a further 6 subjects where the angles in the knee joint were measured on radiographs Zero flexion corresponds here to full passive extension that is angles between the anterior borders of the femur and the tibia that varied from 176 to 192 for the different subjects It is seen here that the moment gradually decreased with the angle of extension and just before full extension a minimum was reached though with wide

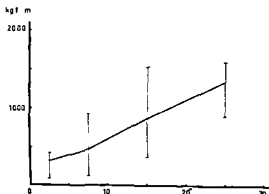


Figure 3 Same as Figure 2 but with means and range for the 6 subjects

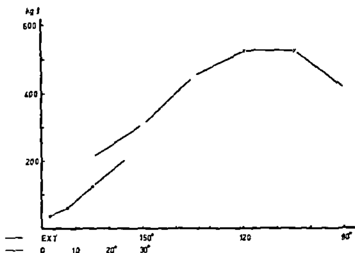


Figure 4 The relationship between the angle of the knee joint and the absolute force exerted by the quadriceps means for 12 subjects The angle is given in the lower curve as flexion measured from full passive extension and in the upper curve as the angle between the thigh and the lower leg

individual variations Figure 3 shows the means obtained from determinations in the individual subjects for the ranges 0–4 5–9 10–19 and 20–29 The means were calculated for all the subjects and all angles within the respective angular ranges The extreme values are the means found for the individual subjects The tendency for the moment to decrease as the joint was extended is clearly depicted in this figure

Figure 4 shows the mean absolute force developed by the quadriceps in different positions of the knee joint Here the measured forces have been combined with the values for the leverage exerted by the quadriceps reported earlier by *Lindahl & Movin* (6) Just like the moment the absolute force diminished steadily with extension from a maximum of 520 kgf between 120 and 150 nearly to zero as full passive extension was approached The two curves do not coincide because they relate to two groups of subjects and different methods for obtaining the position of the knee joint

DISCUSSION

Two problems encountered in measurement of muscular force in extension of the knee joint near the end position are (I) that the force measured distally on the lower leg is extremely small and varies greatly for small changes in angle and (II) it is difficult accurately to deter

mine the angle of the joint The former problem includes the fact that the quadriceps has to overcome not only friction and inertia in the joint and muscle but also some resistance in the antagonist muscles and soft tissues on the flexion side of the knee before any measurable external force can be recorded In the earlier study by *Lindahl & Movin* (7) it was found that even if these factors are taken into account the muscular force in extension is still extremely small of the order of 5–10 kgf

As regards the second problem the nomenclature relating to the position of the knee joint may be confusing because of different systems for designating the positions Moreover in practice it is difficult if not impossible to measure small positional changes with high precision or to say when the knee joint angle is exactly 180 A wide range of positions is obtained depending on whether one uses for the measurement the middle or anterior contours of the thigh and lower leg or the axes of the bones For this reason the authors have defined the various positions It is recommended in each article that the term extension position be used to denote either full passive extension a flexion position then being reckoned from this position or as the angle *between the middle contours of the thigh and the lower leg as seen* from the lateral side For young healthy subjects *Bonde Petersen* (1) has reported values for the force exerted by the quadriceps which are approximately the same as those obtained by the present authors namely 1964 kgf cm for men and 1328 for women both in the 90 position In a study of the force exerted by the quadriceps in different positions of the knee *O Donoghue et al* (8) found a maximum in the semi flexed position and a reduction on extension *Clark* (2) (1966) has reported curves of the relationship between the knee angle and the force of extension that are almost identical with those reported here and that show a maximum at 115 and a rapid decrease towards the extension position No studies have been found in which the absolute force in the quadriceps has been calculated from the leverage conditions for the knee joint

The absolute force per unit of area of the muscle is chiefly of theoretical interest Fick s value of 10 kgf/cm² has not been confirmed by later workers *Haxton* (5) found a value of 3 9 kgf/cm² for human subjects and *Ramsay & Street* (9) 3 5 kgf/cm² for frog muscles Fick s value of 180 cm² for the cross sectional area of the quadriceps would give a mean force of 2 9 kgf/cm² for the subjects of the present study As the determination of the total cross sectional area perpendicular to the

muscle fibres usually involves large theoretical and practical approximations especially for muscles with an oblique direction of the fibres it is hardly surprising that the absolute values for the muscular force vary widely

SUMMARY

The muscular force exerted by the quadriceps in extension of the knee was determined in 12 healthy men aged 20–48 years The force in various positions of the knee joint was measured with a dynamometer The maximum moment of 2300 kgf cm was recorded at 105 –120°, and there was a reduction on further flexion and extension the value approaching zero near full extension

When the leverage conditions in the knee joint were taken into account the absolute force exerted by the quadriceps was a maximum at 105°–120 with a mean of 520 kgf this is equivalent to 2 9 kgf per square centimetre of cross section of the muscle

RESUME

La force musculaire exercee par le quadriceps en extension du genou a ete determinee chez 12 hommes en bonne sante entre 20 et 48 ans La force a été mesuree par un dynamometre dans diverses positions de l articulation du genou Le moment maximum de 2300 kgf cm a ete enregistre a 105 –120 Il y avait une reduction en flexion et extension plus fortes la valeur approchant de zero pres de l extension complete

Lorsqu il est tenu compte des conditions du moment de l articulation du genou la force maximum exercee par le quadriceps est au maximum de 105 –120 avec une moyenne de 520 kgf ceci equivaut à 2 9 kgf par centimetre carre de section transversale du muscle

ZUSAMMENFASSUNG

Die Muskelkraft die vom Quadriceps bei der Kniestreckung ausgeubt wird wurde bei 12 Mannern im Alter von 20–48 Jahren und guten Gesundheitszustand bestimmt Die Kraft wurde mit einem Dynamometer in verschiedenen Stellungen des Kniegelenkes gemessen Das grösste Moment von 2300 kpcm wurde bei 105 –120 aufgezeichnet während eine Verringerung bei weiterer Beugung und Streckung entstand indem der Wert bei nahezu voller Streckung annähern Null war

Wenn die Berechnung der Hebelbedingungen im Kniegelenk vor

genommen wurde war die absolute vom Quadriceps ausgeubte Kraft am grossten bei 105 –120 mit einem Durchschnitt von 520 kgp Dies ist equivalent zu 2 9 kp per Quadratcentimeter des Querschnittes des Muskels

REFERENCES

1 Bonde Petersen F (1960) Muscle training by static concentric and eccentric contractions *Acta physiol scand* 48 406–416

2 Clark, D (1931) Muscle counts of motor units *Amer J Physiol* 96 296–304

3 Demster W T (1961) Free body diagrams as an approach to the mechanics of human posture and motion In Evans G Biomechanical studies of the musculo skeletal system Charles C. Thomas, Springfield Illinois, 1961 pp 81–135

4. Fick, R (1910) Anatomie und Mechanik der Gelenke Verlag von Gustaf Fischer Jena Vol II

5 Haxton H (1944) Absolute muscle force in the ankle flexors of man *J Physiol* 103 267–273

6 Lindahl, O & Movin A (1967) The mechanics of extension of the knee joint. *Acta orthop scand* 38 226–234

7 Lindahl, O & Movin A (1967) Active extension capacity of the knee joint in the healthy subject *Acta orthop scand* 39 203–208

8 O'Donoghue D Tompkins F & Hays M (1952) *Strength of quadriceps function* after patellectomy *West J Surg Obst Gynecol* 60 159–167

9 Ramsey R. & Street S (1940) Isometric length tension diagram of isolated skeletal muscle fibres in frog *J Cell comp Physiol* 15 11–34

Acta orthop Scandinav 40 86-91 1969

From the Department of Orthopaedic Surgery (Chief Professor Carl Hirsch)
Sahlgrenska Sjukhuset University of Goteborg Sweden

REFLEX INHIBITION OF THE QUADRICEPS ELICITED FROM A SUBPERIOSTEAL TUMOUR OF THE FEMUR

By

BERTIL STENER

Received 22.x.67

Inhibition of the thigh extensors is a recognized clinical finding in all manner of afflictions of the knee joint (accidental or surgical trauma infection etc) This arthrogenic inhibition of the quadriceps muscle which may rapidly atrophy as a result has been traditionally attributed to a reflex mechanism *Vulpian's* (1875) theory about this has been repeatedly tested with animal experiments (*Raymond* 1890 *Deroche* 1890 *Hoffa* 1892 *Schiff & Zak* 1912 *Lippman & Selig* 1928) but without conclusive results More recently in the decerebrate cat *Ekholm, Eklund & Skoglund* (1960) have demonstrated inhibition of the monosynaptic arc of the quadriceps induced by distension of the knee joint (artificial effusion) Support for the reflex theory has also been obtained from experiments on man *Stener & Petersen* (1962) showed that the vastus medialis is reflexly inhibited when pain receptors are stimulated in the medial collateral ligament of the knee joint and *de Andrade Grant & Dixon* (1965) found that an increase in the intra articular pressure in the knee joint induces reflex inhibition of the quadriceps muscle

This report concerns a patient in whom pronounced atrophy of the quadriceps is believed to have been due to reflex inhibition of the muscle initiated by a subperiosteal femoral tumour situated near the knee joint

CASE REPORT

A 45 year old man had a three year history of pain in the right knee. On examination a firm tender lump the size of half of a walnut was palpated proximal to



Figure 1 A thin piece of bone can be seen protruding from the femur proximal to the lateral epicondyle corresponding to the proximal border of the tumour

the lateral femoral epicondyle it was free in relation to the skin but had a deep attachment. An X ray examination of this site revealed a thin piece of bone protruding from the femur (Figure 1) Extension and flexion of the knee joint elicited pain within but not outside the range of 30 to 60 of flexion The quadriceps muscle had atrophied to a considerable extent. The circumference of the thigh 20 cm proximal to the knee joint was 3 cm less on the affected side

Pressure on the tender lump was found to inhibit active extension in the knee joint. This was demonstrated both clinically and electromyographically The patient sat on a table so that his thigh was supported but the lower leg hung freely over the edge he was then asked to extend the knee as much as he could When pressure was applied to the lump he was quite unable to keep the leg in a horizontal position —the knee flexed against his will Electromyography (Figure 2) showed that this inhibition affected the vastus lateralis and vastus medialis in particular whereas the rectus femoris hardly changed at all.

At operation in a bloodless field (Figure 3) the lump proved to be a subperiosteal tumour of the femur It was excised in toto together with the periosteum covering it on the superficial side (Figure 3 below × 1 3) and cancellous bone on the deep

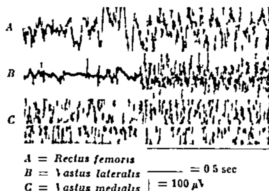


Figure 2 Electromyography of the rectus femoris vastus lateralis and vastus medialis Pressure on the tender lump (signal line) elicited marked inhibition of the voluntary activity in the vastus lateralis and vastus medialis but little change in the rectus femoris

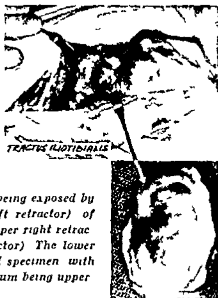


Figure 3 The operative field The tumour is being exposed by retraction of the vastus lateralis (upper left retractor) of the synovial membrane of the knee joint (upper right retractor) and of the iliotibial band (lower retractor) The lower picture shows an enlargement of the excised specimen with the surface of the tumour covered by periosteum being uppermost (scale in mm)

side The tumour was sectioned and found to be lobulated and to consist of soft greyish red to dark red tissue

Microscopic examination (Assoc. prof *L Angervall*) showed the tumour to be relatively acellular with pronounced degenerative changes and extensive necrosis and haemorrhage Many of the cells were polygonal or star shaped and had irregular nucleoli No mitoses were seen The tumour was mostly myxoid although signs of intracellular hyaline formation were detectable here and there The fibrous capsule (the periosteum) contained bone The histological diagnosis was chondroma with regressive changes possibly a chondromyxoid fibroma There was no evidence of malignancy

The postoperative course was uncomplicated and the function of the quadriceps improved rapidly The patient was free of symptoms seven weeks after the operation and returned to full time employment as a ship s mechanic

DISCUSSION

Pressure exerted upon a tender lump that subsequently proved to be a subperiosteal femoral tumour elicited inhibition of active extension of the knee joint It seems that this inhibition which the patient could not counteract was due to a reflex mechanism initiated by the stimulation of pain receptors

A study of the patient s spontaneous pain showed that this was experienced during movements of the knee joint within but not outside the range of 30 to 60 of flexion A possible explanation illustrated in Figure 4 is that the iliotibial band irritated the tumour when it passed

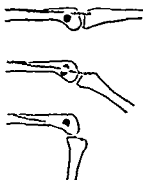


Figure 4 Diagram to illustrate how the iliotibial band may have had a mechanical effect on the tumour during flexion and extension of the knee joint within the range of 30 to 60 of flexion i e the range within which pain was elicited

over the latter s most prominent part during movements within this range The finding of pronounced atrophy of the quadriceps could then be entirely or partly ascribed to this muscle having been subjected for a long time to reflex inhibition elicited by pain inducing mechanical effect on the tumour Such an explanation is supported by the fact that the function of the quadriceps rapidly improved after removal of the tumour

Electromyography showed that the inhibition of the quadriceps affected the vastus lateralis and vastus medialis in particular whereas the rectus femoris displayed little change This difference may be due to the fact that the rectus femoris besides being a knee extensor is also involved in flexion of the hip The reflex response indicated by Figure 2 in fact conforms with the general flexion reflex that *Sherrington (1910)* has described as *being elicited on painful stimulation of* the lower extremity In this reflex which includes flexion of both the knee and the hip joint the rectus femoris functions as a hip flexor rather than a knee extensor since it is activated at the same time as the vastus lateralis and vastus medialis are inhibited

SUMMARY

Muscle wasting caused by nociceptive reflex motor inhibition is often seen following injury to the knee joint The same phenomenon has been observed in a case of a subperiosteal cartilagionus tumour located proximal to the lateral femoral epicondyle The tumour was tender on palpation and pain was also experienced during movement of the knee joint within the range of 30 to 60 of flexion The quadriceps muscle was atrophied to a great extent Pressure on the tumour during active contraction of the quadriceps caused instantaneous loss of muscle

power. Similarly, electromyography showed that voluntary activity in the vastus lateralis and vastus medialis was inhibited after short latency by pressure on the tumour. On removal of the tumour the pain disappeared and the function of the quadriceps improved rapidly.

The pain experienced during movement of the knee joint is explained by the location of the tumour in relation to the iliotibial band. Within the painful range mentioned the iliotibial band exerted pressure on the tender tumour. It is probable that this mechanism elicited an inhibitory reflex resulting in atrophy of the quadriceps.

RÉSUMÉ

Une amyotrophie qui est le résultat d'une inhibition motrice élicitée par un réflexe nociceptif est souvent observée à la suite d'une lésion de l'articulation du genou. Le même phénomène a été constaté dans un cas de tumeur cartilagineuse sous-périostale localisée à l'épicondyle fémoral latéral. La tumeur était sensible à la palpation et on a aussi constaté des douleurs durant les mouvements de l'articulation du genou entre 30 et 60 degrés de flexion. Le muscle quadriceps était fortement atrophié. La pression exercée sur la tumeur pendant une contraction active du quadriceps causa une perte instantanée de la force du muscle. De la même façon, l'électromyographie montrait que l'activité volontaire du vaste latéral et du vaste interne était empêchée après une courte période de latence par la pression sur la tumeur. La tumeur enlevée, la douleur a disparu et la fonction du quadriceps s'est améliorée rapidement.

La douleur éprouvée durant les mouvements de l'articulation du genou entre les degrés mentionnés s'explique par la localisation de la tumeur par rapport au ligament ilio-tibial. Durant ces mouvements, le ligament ilio-tibial exerçait une pression sur la tumeur qui y était sensible. Il est probable que ce mécanisme déclenchait un réflexe inhibiteur donnant comme résultat l'atrophie du quadriceps.

ZUSAMMENFASSUNG

Nach Verletzung des Kniegelenkes wird oft eine durch nociceptiven Reflex bedingte motorische Hemmung und eine dadurch verursachte Muskelatrophie festgestellt. Die gleiche Erscheinung wurde in einem Fall eines subperiostalen cartilaginösen Tumors beobachtet, der proximal des lateralen Femurepicondylus lokalisiert war. Der Tumor war empfindlich auf Berührung. Schmerzen wurden auch bei Bewegung

des Kniegelenkes innerhalb des Bereiches von 30–60° Beugung empfunden. Der Quadricepsmuskel war hochgradig atrophisch. Druck auf den Tumor wärend aktiver Quadricepskontraktion verursachte den augenblicklichen Verlust der Muskelkraft. Die Elektromyographie zeigte in gleicher Weise, dass die willkürliche Aktivität im Vastus medialis und lateralis nach einer kurzen Latenzzeit durch Druck auf den Tumor gehemmt wurde. Nach Entfernung des Tumors verschwanden die Schmerzen und die Quadricepsfunktion besserte sich rasch. Die wärend der Bewegung des Kniegelenkes auftretenden Schmerzen werden durch den Sitz des Tumors in Bezug auf das Lig. ilio-tibiale erklärt. Innerhalb des erwähnten schmerzhaften Bereiches übte das Lig. ilio-tibiale einen Druck auf den empfindlichen Tumor aus. Es ist wahrscheinlich, dass dieser Mechanismus einen Hemmungsreflex hervorrief, der die Atrophie des Quadriceps zur Folge hatte.

REFERENCES

de Andrade, J. R., Grant, D. & Dixon, A. St. J. (1965) Joint Distension and Reflex Muscle Inhibition in the Knee. *J. Bone Jt. Surg.* 47 A, 313–322.

Deroche, R. (1890) Étude clinique et expérimentale sur les amyotrophies reflexes d'origine articulaire. G. Steinheil, Éditeur, Paris.

Ekholm, J., Eklund, G. & Skoglund, S. (1960) On the Reflex Effects from the Knee Joint of the Cat. *Acta physiol. scand.* 50, 167–174.

Hoffa, A. (1892) Zur Pathogonese der arthritischen Muskelatrophien. *Sammlung Klinischer Vortrage.* Neue Folge, No. 50.

Lippmann, R. K. & Selig, S. (1928) An Experimental Study of Muscle Atrophy. *Surg. Gynec. Obstet.* 47, 512–522.

Raymond (1890) Recherches experimentales sur la pathogénie des atrophies musculaires consecutives aux arthrites traumatiques. *Rev. Méd.* 374–391.

Schiff, A. & Zak, E. (1912) Experimentelle Untersuchungen zur Pathogenese der arthritischen Muskelatrophien. *Wien. klin. Wschr.* 651–658.

Sherrington, C. S. (1910) Flexion Reflex of the Limb, Crossed Extension Reflex and Reflex Stepping and Standing. *J. Physiol.* 40, 28–121.

Stener, B. & Petersén, I. (1962) Electromyographic Investigation of Reflex Effects Upon Stretching the Partially Ruptured Medial Collateral Ligament of the Knee Joint. *Acta chir. scand.* 124, 396–415.

Vulpian, E. F. (1875) Leçons sur l'appareil vasomoteur. Gerner Ballière et Cie, Paris. (Quoted by Lippman & Selig, see above.)

Acta orthop Scandinav 40 92–104 1969

From the Orthopaedic Hospital Aarhus Denmark
(Head Professor Eivind Thomasen M D)

TREATMENT OF DELAYED UNION AND NON UNION OF THE TIBIA BY FIBULAR RESECTION

By

K Harry Sorensen

Received 2 XII 67

The treatment of pseudo arthrosis of the tibia or delayed union following fracture is still a difficult orthopaedic problem

As a rule the treatment consists in grafting either in the form of a tibial or iliac bone graft combined with freshening of the fracture ends and possibly metal fixation In some cases an iliac bone graft is inserted into the defect following resection of the pseudo arthrosis or fixation with plate and screws is used while in other cases the procedure is restricted to the insertion of a graft or chips at the fracture site Some surgeons do tibio fibular synostosis As a rule these are major procedures which require great experience and technical skill In spite of repeated operations it is in some cases impossible to obtain union, and in a few instances the procedures are complicated by infection which may prevent union

The considerations concerning the causes of non union sometimes include the assumption that the tibial ends are kept apart by the fibula Among 175 tibial fractures with intact fibula *Nicoll* (1964) found delayed union or non union in 9 per cent as compared with 29 per cent out of 499 cases in which the fibula was fractured too Therefore the fibula was considered to play a role only by influencing the initial displacement of the fracture ends

In the comprehensive literature on the treatment of delayed union or non union of tibial fractures fibular osteotomy is but seldom mentioned and only in connection with other forms of surgery on the tibia

Among 100 cases of delayed union or non union of tibial fractures *Sakellarides et al* (1964) carried out fibular osteotomy in 22 cases

simultaneously with grafting the tibia Union took 10 7 months on an average compared with 10 9 months for 34 fractures treated in the same way but without fibular osteotomy The osteotomy facilitated the correction of faulty positions and the placement of the fracture ends especially in the presence of bony defects

Koskinen (1963) used fibular osteotomy combined with compression of the fractured ends of the tibia by means of Steinmann s pins in 2 out of 4 cases of delayed or non union Both united in 7 and 8 months

In combination with Hoffmann osteotaxis *Fellander* (1963) performed fibular osteotomy on 2 out of 14 tibial pseudarthroses One failed to unite

Simple osteotomy on the fibula can hardly be attributed with major importance since as a rule the fibula will undergo solid union within 3 months as it is amply vascularized while the tibia requires 7–10 months to unite Therefore a piece of the fibula has to be resected so that it does not unite before the tibia

Lottes (1966) always resects at least 2 5 cm of the fibula in combination with medullary nailing of the tibia in cases of delayed or non union No other authors have recommended the routine use of fibular resection

METHOD

Since 1955 the treatment of delayed union or non union of the tibia at the Orthopaedic Hospital Aarhus has consisted in resection of a piece of the fibula on a level with the tibial fracture which was not touched After the operation a plaster cast is applied from the toes to high up on the thigh until union occurs If the tibia has been sclerotic and therefore stiffer and more brittle the plaster cast is followed by a foot leg capsule of leather for a few months as a prophylaxis against re fracture

MATERIAL

From 1955 to 1 4 1965 29 patients (pts.) with 30 fractured legs were treated 8 were females (9 legs) and 21 males All were fairly young 6 females and 12 males being under 30 (Table 1) 18 pts. (19 legs) had been injured in traffic accidents including 12 on motor cycles Out of 20 complicated fractures 16 had been sustained in traffic accidents The fibula was fractured in 26 cases 27 fractures were localized 5–18 cm above the ankle joint 10 were comminuted 8 were transverse fractures 12 oblique fractures or spiral fractures Two patients had bilateral tibial fracture and 3 homolateral fracture of the femur

20 legs including 11 with complicated fractures had been treated in the local hospitals by primary osteosynthesis (6 Rush pins 7 Parham s bands plate and screws 7) The metal had been removed in all cases at the end of an average period of 7 (3–17) months Two legs underwent re operation 3 and 13 days after

the primary operation because of instability at the fracture site. Both fractu
were complicated.

At an early stage 7 developed osteitis combined with necrosis of the skin in
Five of these fractures were complicated. Primary osteosynthesis had been perform
on 5 Another leg exhibited paresis of ischaemic origin and contracture of the f
in the equinus position

Table 1 Age distribution and sex ratio of 29 patients (30 legs) with non union delayed union of the tibia stating the type of accident (mc = motor cycle)

Age	Males	Females	Traffic	(mc)	Workplace	Sport	Tot
14–19 years	3	4	4	(2)	2	1	7
20–29	9	2(3)	9(10)	(7)	1	1	11(1
30–39	4		3	(2)	1		4
40–49	5		2	(1)	2	1	5
60–66		2			2		2
Total	21	8(9)	18(19)	(12)	8	3	29(3
Complicated	15	4(5)	15(16)	(10)	3	1	19(
Right	14	3					
Left	7	6					

Table 2 Duration of plaster treatment primarily and following fibular resecti (FR) and duration of completed leather foot leg capsule bandaging The figures refer to the number of legs

Duration (months)	Plaster cast		Leather capsul
	Primary	After FR	
1–4	6	5	
5–8	8	20	8
10–15	9	2	3
18–22	6	2	2
28–34	1	1	1
Still wearing bandage		2	8
Average duration of bandaging	11	7 5	11

Average 6 months

Owing to non union secondary operation had been carried out on 8 legs Drillin of the fracture ends by the method of Beck 3 legs grafting 4 legs, fibular resectio and later re-osteosynthesis using Rush pins 1 leg These operations had been per formed an average of 8 (4–11) months after the accident.

When the patients were referred to the Orthopaedic Hospital, Aarhus they had been in plaster for an average of 11 months (Table 2) In two cases a toe to knee cast had been used 18 legs exhibited non union and 12 delayed union

At the Orthopaedic Hospital they were treated by fibular resection performed in cases of non union an average of 26 months after the accident and in cases of delayed union at the end of 10 months (Table 3) Apart from a defect in the operative wound in 1 patient, which healed in 3 months there were no complications. The defect in the fibula was measured radiographically after the operation and application of plaster cast it ranged from 0.2–6.5 cm in length (Table 4)

Table 3 Time of fibular resection (FR) after accident

No of legs		FR months after accident	
		Range	Average
	10	6–11	8
	14	13–23	18
	4	24–33	29
	2	63–79	71
Delayed union	12	6–18	10
Non union	18	10–79	26

Table 4 Fibular defect measured radiographically after the operation and application of plaster cast At the bottom Fibular defect at the time of analysis when 26 tibial fractures had united The fibula had united in 7 cases

Defect cm	0.2–0.7	1–2	2–3	3–4	4–5	5–6	6–7
30 legs	5	5	6	7	3	3	1
19 legs at the time of analysis	4	7	3	2	2	1	

After the fibular resection a plaster cast was applied from the toes to high up on the thigh and this cast was left on for an average of 7.5 months (Table 2) When disregarding 3 cases in which the cast was kept for a very long time there was no relationship between the duration of this bandaging and the time which had passed from the fracture until the fibular resection 17 patients were discharged at the end of about two weeks with a Thomas splint over the cast The stay in hospital was very short. Weight bearing was allowed after an average of 7 months (25 pts after an average of 5 months and 5 after 16 months) After the plaster cast had been removed 21 patients (22 legs) were supplied with a leather foot leg capsule which 14 of them wore for an average of 11 months (Table 2) while 7 were still wearing it at the time of writing



Figure 1 A 29 year old man with a complicated fracture of the lower leg Primary osteosynthesis with plate and screws removed at the end of 5 months because of cutaneous necrosis and osteitis After chiselling off the bony necrosis a plaster cast was applied and worn until 17 months after the accident Thereafter fibular resection and removal of sequester The skin had healed 2 months later The fibula rapidly united (radiologically the defect was only 0.5 cm) Re resection of the fibula was done 10 months after the first resection 9 mo later the fracture was firm (36 mo after the accident) Thereafter a leather capsule has been worn so far for 11 mo No osteitis The films show (a) 13 mo after the accident A large defect in the tibia osteitis The fibula has united (resection 4 mo later) (b) 46 mo after the accident (20 mo after the second fibular resection) Union but the fracture line may be discerned Sclerosis but no increase in width A 5¼ cm fibular defect

RESULTS

Union was obtained in the case of 26 fractures while 4 have not yet united

Among the 25 pts who obtained union 2 had *re fracture* following an adequate trauma The fractures united one after treatment in plaster cast and the other after a tibial grafting done abroad

In 4 cases there were *problems concerning the union* In 2 the fibula healed too fast as too little had been resected After re resection of the fibula and plaster cast, union was obtained (Figure 1) In 2 pts union was again followed by looseness 11 and 16 months after the fibular resection Union was then obtained after renewed bandaging in one of the cases merely by continuing the use of a leather foot leg capsule, which resulted in firm union 5 months later

At the time of analysis an average of 41 months after the fibular resection, 26 pts exhibited bony union 9 had not had leather bandage after the plaster cast 12 patients had stopped using the leather ban dage, while 5 were still wearing it

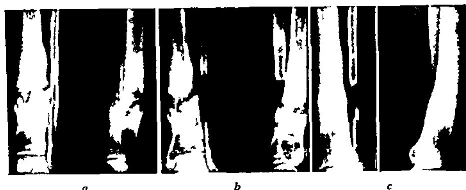


Figure 2 A girl aged 16 years The tibial fracture had been treated primarily by Parham's band and plaster cast for 4 mo Thereafter the Parham band was removed Weight bearing 5 months after the accident (a) 12 mo after the accident just before the fibular resection (b) Immediately after fibular resection 6 mo later there was firm union of the fracture and weight bearing was possible without a bandage (c) 48 mo after fibular resection Solid union of the tibial fracture with a near normal bony structure The fibular defect is still visible

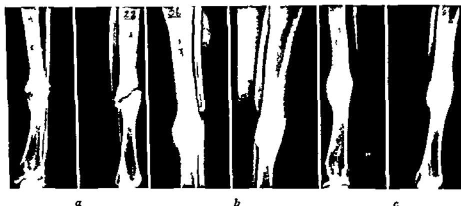


Figure 3 A man aged 33 years Complicated tibial fracture treated with plaster cast and 4 mo later drilling by the method of Beck and Parham's band which was removed 4 mo later Plaster cast for a total of 13 mo (a) 22 mo after the accident Non union with sclerosis increased width and closed medullary cavities Note the arched (not fractured) fibula keeping the fragments apart! (b) 36 mo after the accident (12 mo after fibular resection) The pt wore a plaster cast for 4 mo after the fibular resection and then weight bearing was allowed in a leather foot lower leg capsule which was worn for 9 months The film now shows smoothing of the surface but still sclerosis The increase in width has decreased from 47 to 40 mm. (c) 8? mo after the accident (60 mo after the fibular resection) Further normaliza tion Still a ¾ cm defect in the fibula. (The pt has no subjective complaints All joints are free and there is no shortening The circumference of the thigh is reduced by 1 cm and that of the lower leg by ? cm)

Radiologically the union was solid in all 26 cases There was slight angulation (less than 10°) at the fracture site in 7 The skeletal structure at the fracture site was normal in 11, while 5 exhibited slight and 10 more pronounced sclerosis in an area of 2–8 cm The thickness of the tibia at the fracture site was normal in 14, while in 12 it was thickened in both views, by an average of 12 mm The fibula had united in 7, while in 19 there remained a defect of 0 2–5 5 cm at the site of resection (Table 4) There was no displacement between the two bone ends, no subjective complaints that could be ascribed to the defect and no tenderness at its site (Figures 2–3)

In 4 cases union was not obtained Two of these patients are still wearing the plaster cast, and union is expected Both developed looseness after union had been obtained (cf case reports 1–4)

CASE REPORTS

Case 1 A 47 year old man with bilateral complicated fracture of the lower leg. The fracture on the right healed with a plaster cast. The left leg was primarily fixed by plating an iliac bone graft, and plaster At the end of 10 months (mo) a tibial sliding graft was inserted but 8 months later there was non union in spite of a plaster cast. After fibular resection and plaster cast the fracture remained non united so that 6 months later an iliac graft was inserted and chips were applied around the fracture site after removal of the plate After a plaster cast had been worn for 12 months the fracture was firm Although the patient wore a leather capsule looseness occurred 4 months later when he fell off his bicycle After another 4 months with a plaster cast, the patient refused further treatment except for the leather capsule 71 months after the fracture had been sustained amputation of the lower leg had to be performed.

Case 2 A 45 year old bricklayer with a comminuted complicated fracture of the lower leg primarily treated with cerclage and plaster cast. Necrosis of the skin and a defect with osteitis persisted for months. The cerclage was removed at the end of 3 months and 11 months after the accident fibular resection 11 cm above the fracture site was performed in the local hospital 24 months after the accident 2 Rush pins and an iliac graft were in erted but skin necrosis recurred. The patient wore a plaster cast for a total of 33 months Looseness was observed 62 months after the accident, and the 2 Rush pins were removed. One month later fibular resection was performed with application of plaster cast + Thomas splint. There was slight instability at the end of 6 months Thereafter a leather capsule was worn for 5 months and a plaster cast for 8 months. 79 months after the accident the fracture was firm and remained so for 15 months during which the patient wore a leather capsule. Then he again exhibited looseness and signs of arterial insufficiency (no palpable pulse in the popliteal region or on the foot) Amputation of the lower leg was suggested, but the patient managed his work in an architect s office without complaints and did not want to have the operation

Case 3 A 22 year old woman with bilateral complicated fracture of the legs both treated with Rush pins Parham s bands and plaster cast for 22 months When the metal was removed there was considerable looseness Fibular resection was done on both sides Radiologically the fibular defect on both sides was only 0 2 cm The *left* tibia was firm at the end of 3 months and the fibula had united The patient walked in a plaster cast for 2 months and was then provided with a leather capsule Looseness was demonstrated 11 months after the fibular resection but 5 months later the fracture was stable 41 months after the fibular resection the site was still firm and the patient had no symptoms but she was still wearing the leather capsule as the right tibia was not firm

On the right the fibula united in 3 months At that time the tibia was firm The patient walked in a plaster cast for 5 months Thereafter the tibia was loose and re resection of the fibula was performed so that the defect was 2 1 cm on the X ray film 10 months later there was still looseness in spite of a plaster cast without weight bearing The patient was now pregnant and managed with a leather capsule for 10 months Thereafter a tibial sliding grafting was done 7 months later while she was confined to bed before a new cast had to be applied and the site showed firmness fracture of the graft and looseness occurred After another 7 months in a plaster cast there was firmness and X rays showed union by a fairly slender bone through two thirds of the fracture The patient is still wearing the plaster cast

Case 4 A 66 year old woman. The fracture had been treated primarily by 3 Parham bands on the tibia removed 7 months later During the first 4 months after the accident the patient wore a plaster cast from the toes to the middle of the thigh thereafter to the knee for 6 months, after which weight bearing without a cast had been allowed. 9 months later there was looseness so that a plaster cast was again applied to the middle of the thigh and worn for 3 months. Two months later fibular resection was performed and after a plaster cast had been worn for 7 months firmness had been obtained. After 17 months in a leather capsule instability had returned So far the patient has been wearing a plaster cast to the middle of the thigh for 5 months. X rays show signs of union and there is no indication of pseudoarthrosis. The fibular defect measures 2 cm. Union is expected to occur

DISCUSSION

Fibular resection followed by application of plaster cast does not appear to have been described in the literature as *treatment of non union* or delayed union of the tibia

The *advantages* of this method are as follows

1) The operation is technically easy and can be performed by younger and less experienced surgeons than all other current procedures
2) Faulty positions at the fracture site are easy to correct.
3) Effective compression at the fracture site is secured until union occurs but only if a sufficient portion of the fibula is resected *i e* 3–4 cm When measured on the X ray film through the plaster the

Radiologically the union was solid in all 26 cases There was slight angulation (less than 10°) at the fracture site in 7 The skeletal structure at the fracture site was normal in 11 while 5 exhibited slight and 10 more pronounced sclerosis in an area of 2–8 cm The thickness of the tibia at the fracture site was normal in 14, while in 12 it was thickened in both views by an average of 12 mm The fibula had united in 7, while in 19 there remained a defect of 0 2–5 5 cm at the site of resection (Table 4) There was no displacement between the two bone ends no subjective complaints that could be ascribed to the defect and no tenderness at its site (Figures 2–3)

In 4 cases union was not obtained Two of these patients are still wearing the plaster cast, and union is expected Both developed looseness after union had been obtained (cf case reports 1–4)

CASE REPORTS

Case 1 A 47 year old man with bilateral complicated fracture of the lower leg. The fracture on the right healed with a plaster cast The left leg was primarily fixed by plating an iliac bone graft and plaster At the end of 10 months (mo) a tibial sliding graft was inserted, but 8 months later there was non union in spite of a plaster cast After fibular resection and plaster cast the fracture remained non united so that 6 months later an iliac graft was inserted and chips were applied around the fracture site after removal of the plate After a plaster cast had been worn for 12 months the fracture was firm Although the patient wore a leather capsule looseness occurred 4 months later when he fell off his bicycle After another 4 months with a plaster cast the patient refused further treatment except for the leather capsule 71 months after the fracture had been sustained amputation of the lower leg had to be performed

Case 2 A 45 year old bricklayer with a comminuted complicated fracture of the lower leg primarily treated with cerclage and plaster cast Necrosis of the skin and a defect with osteitis persisted for months The cerclage was removed at the end of 3 months and 11 months after the accident fibular resection 11 cm above the fracture site was performed in the local hospital 24 months after the accident 2 Rush pins and an iliac graft were inserted but skin necrosis recurred The patient wore a plaster cast for a total of 33 months Looseness was observed 62 months after the accident, and the 2 Rush pins were removed. One month later fibular resection was performed with application of plaster cast + Thomas splint. There was slight instability at the end of 6 months Thereafter a leather capsule was worn for 5 months and a plaster cast for 8 months 79 months after the accident the fracture was firm and remained so for 15 months during which the patient wore a leather capsule. Then he again exhibited looseness and signs of arterial insufficiency (no palpable pulse in the popliteal region or on the foot) Amputation of the lower leg was suggested but the patient managed his work in an architect's office without complaints and did not want to have the operation

The *time required for union* which in this heavy material averaged 7½ months is no longer than following other more complicated surgical methods Following osteotaxis by the method of Hoffmann in combination with pseudo arthrosis surgery *Fellander* (1963) found an average healing time of 5 months Following bone grafting *Sakellarides et al* (1964) found a healing time of 9–11 months while *Murray et al* (1964) obtained union in 7 months following fixation with 2 plates

The results assessed by the rate of union and the frequency of amputations correspond largely to those obtained by other more complicated methods (Table 5)

SUMMARY

Eighteen cases of tibial pseudo arthrosis and 12 cases of delayed union were treated exclusively by extraperiosteal resection of a piece of the fibula on a level with the fracture followed by application of toe to groin plaster cast

Primary osteosynthesis using metal fixation had been performed in 20 cases elsewhere among these fractures 11 were complicated Osteitis was present in 7 cases In 8 cases a pseudo arthrosis operation had been carried out previously The patients had worn plaster casts for an average of 11 months when the fibular resection was done Union was obtained after the plaster cast had been on for an average of 7½ months Thereafter 21 patients wore a leather foot lower leg capsule for about 1 year to protect from re fracture in the event of bony sclerosis around the fracture site

Union was obtained in 26 cases and all the cases of osteitis subsided Two patients had re fracture following new trauma but union was obtained In 2 cases the fibula healed too soon as too little had been resected but union was obtained following re resection A few months later 2 patients had looseness again but union was obtained after bandaging

Four fractures failed to unite In all 4 cases firmness had been obtained One sustained re fracture following trauma and later had to undergo amputation and one is managing in a leather capsule Two patients are still wearing the plaster cast and union is expected to occur

The method is simple and easy It may be carried out by less experienced surgeons and it permits correction of faulty positions Effective compression at the fracture site is obtained until union occurs if

SMS MEDICAL COLLEGE

3–4 cm of the fibula are resected extraperiosteally There is no risk of infection or damage to the vascular supply to the fracture The patients can soon be mobilized and discharged The method is applicable without risk in the event of a suspicion of problematic union, prior to the development of osseous changes which lead to pseudo arthrosis With this method in reserve hazardous primary operations may be avoided This is of the utmost importance as infection, delayed union and development of pseudo arthrosis have increased in frequency after primary operative treatment came into more common use

RESUME

Dix huit cas de pseudarthrose tibiale et 12 cas de soudure differée ont ete traites exclusivement par resection extraperiostale d un morceau du perone au niveau de la fracture, suivie de l application d un platre allant des orteils a la cuisse

Une osteosynthése primaire utilisant une fixation metallique a éte pratiquee ailleurs dans 20 cas parmi ces fractures, 11 etaient compliquees Une ostéite existait dans 7 cas Dans 8 cas une operation de pseudarthrose avait eté pratiquee antérieurement Les malades avaient porte une forme en platre pendant une moyenne de 11 mois lorsque la resection du perone fut faite La soudure fut obtenue après le port du platre pendant 7 mois et demi en moyenne 21 malades portèrent ensuite pendant environ un an une gaine en cuir enfermant le pied et le bas de la jambe pour empecher une nouvelle fracture dans le cas d une sclérose osseuse du cote de la fracture

La soudure a ete obtenue dans 26 cas et dans tous les cas d osteite celle ci a diminue Deux malades ont subi une nouvelle fracture a la suite d un nouveau trauma mais la soudure fut obtenue Dans 2 cas le *perone s est gueri trop rapidement une trop petite partie ayant ete* enlevee mais la soudure fut obtenue apres une nouvelle resection Quelques mois plus tard il se produisit un relâchement chez 2 malades mais la soudure fut obtenue après l application d un bandage

Dans quatre fractures il n y a pas eu de soudure, mais la fermeté a éte obtenue dans tous les quatre cas L un fut atteint d une nouvelle fracture a la suite d un trauma et dut subir plus tard une amputation un autre se debrouille avec une gaine de cuir Deux malades continuent a porter une forme en platre et l on suppose que la soudure se fera

La methode est simple et facile Elle peut etre pratiquee par des chirurgiens qui n ont pas une grande experience et permet la correction

de positions fausses Une compression efficace du cote de la fracture est obtenus jusqu a ce que la soudure se fasse en pratiquant une resection extraperiostale de 3–4 cm du perone Il n y a aucun risque d infection ou de dommages a l approvisionnement vasculaire de la fracture Les malades peuvent etre rapidement mobilises et gueris Meme si l on soupçonne une soudure problematique la methode est applicable sans risques avant le developpement de modifications osse uses *menant a une pseudarthrose* Avec *cette methode en reserve* on peut eviter des operations primaires hasardees Ceci est de la plus haute importance etant donne que les infections les soudures differees et le developpement de la pseudarthrose apparaissent beaucoup plus frequemment depuis que le traitement operatoire primaire est devenu plus courant

ZUSAMMENFASSUNG

Achtzehn Falle von Tibiapseudarthrose und 12 Falle von verzogerter Heilung wurden ausschliesslich mittels extraperiostaler Resektion eines Stuckes der Fibula in der Hohe des Bruches mit folgender Anlegung eines Gipsverbandes von den Zehen bis zur Leistengegend behandelt

Ursprungliche Osteosynthese mittels Metallfixierung war in 20 Fallen anderswo ausgefuhrt worden 11 von diesen Bruchen waren kompliziert Osteitis war in 7 Fallen vorhanden In 8 Fallen war vorher eine Pseu darthroseoperation ausgeführt worden Die Patienten hatten im Durch schnitt einen Gipsverband von 11 Monaten getragen wenn die Resektion der Fibula vorgenommen wurde Heilung wurde erzielt nachdem der Gipsverband durchschnittlich fur 7½ Monate belassen worden war Hernach brauchten 21 Patienten eine Lederhulse fur Unterschenkel Fuss wahrend ungefahr eines Jahres um eine Refraktur im Falle einer *Knochensklerosierung an der Bruchstelle zu verhindern*

Knocherne Heilung wurde in 26 Fallen erhalten und Osteitis ver schwandt in allen Fallen Zwei Patienten hatten eine Refraktur nach neuem Trauma aber Heilung wurde erzielt In zwei Fallen heilte die Fibula zu rasch da zu wenig reseziert worden war aber Heilung wurde nach einer Re resektion erhalten Einige Monate später zeigten 2 Pa tienten wiederum Lockerheit aber Heilung wurde nach erneuter Ver bandanlegung erzielt

Vier Bruche heilten nicht In allen 4 Fallen war Festigkeit erzielt worden Ein Fall bekam eine Refraktur nach einem Trauma und musste spater amputiert werden und ein anderer behilft sich mit einer

Lederhulse Zwei Patienten tragen noch einen Gipsverband und ma erwartet dass Heilung eintreten wird

Die Methode ist einfach und leicht Sie kann von weniger erfahrene Chirurgen ausgefuhrt werden und erlaubt Korrektur von Fehlste lungen Effektive Kompression der Bruchstelle wird erhalten bis d Heilung eintritt wenn 3–4 cm der Fibula extraperiostal reseziert we den Keinerlei Gefahr einer Infektion oder Schadigung der Gefassve sorgung des Bruches ist vorhanden Der Patient kann bald mobilisie und entlassen werden Die Methode kann ohne Gefahr im Falle de Verdachtes einer zweifelhaften Vereinigung vor der Entwicklung vo Knochenveranderungen, die zur Pseudarthrose fuhren angewende werden Mit dieser Methode in der Reserve konnten gewagte primai Operationen vermieden werden Dies ist ausserst wichtig da Infektioi verspatete Heilung und Entwicklung von Pseudarthrosen an Haufig keit seit die primäre operative Behandlung allgemeiner verwende wird zugenommen haben

REFERENCES

Anderson G (1966) Bone grafts for delayed union and non union of the tibi *J Bone Jt Surg 48B* 591

Bistrom O (1955) On the treatment of pseudarthrosis and retarded consolidatioi *Acta orthop scand 24* 339–340

Fellander M (1963) Treatment of fractures and pseudarthroses of the long bone by Hoffmann s transfixation method (osteotaxis) *Acta orthop scand* 3: 132–150

Hanson L W & Eppright R H (1966) Posterior bone grafting of the tibia for non union *J Bone Jt Surg* 48A 27–42

Koskinen E V S (1963) The effect of growth hormone and thyreotropin on huma fracture healing *Acta orthop scand* suppl no 62 14–15

Lottes J O (1966) Treatment of delayed or nonunion fractures of the tibia by medullary nail *Clin Orthop* 43 111–128

Murray W R Lucas D B & Inman V T (1964) Treatment of non union of frac tures of the long bones by the two plate method *J Bone Jt Surg* 46A 1027– 1048

Nicoll E A (1964) Fractures of the tibial shaft *J Bone Jt Surg* 46B 373–387

Nyberg L (1955) On pseudarthrosis treatment at the Invalid Institute s Hospital in Helsingfors Acta orthop scand 24 340

Sakellarides H T Freeman P A & Grant B D (1964) Delayed union and non union of tibial shaft fractures A review of 100 cases *J Bone Jt Surg* 46A 557–569

Sevastikoglou J A (1965) Operative treatment of non united fractures of *long* bones *Acta orthop scand* 36 192–201

Acta orthop Scandinav 40 105-118 1969

From the Fracture and Orthopaedic Unit Bridge of Earn Hospital Perthshire Scotland (Head Prof I S Smillie)

FIBULAR RESECTION IN DELAYED UNION OF TIBIAL FRACTURES

By

FEDERICO FERNANDEZ PALAZZI[1]

Received 24 viii 67

With modern methods of treatment delayed union of tibial fractures is no longer a major problem Nevertheless the problem still exists and it is the purpose of this paper to correlate the presence of an intact fibula in slow union of the tibia an intact fibula in the adult apparently preventing satisfactory contact between the tibial fragments

Delayed union of the tibia frequently occurs in the presence of such an intact fibula In some cases the fibula is not damaged at the time of injury and then exerts its deleterious influence from an early stage (a primary intact fibula) On occasions the fibula is fractured initially but unites rapidly and thereafter prevents contact between the tibial fragments

The incidence of non union and delayed union varies from bone to bone and is highest for the tibia (*Campbell* 1963) It is well recognized that fractures of the tibia specially in the lower middle third and in older patients heal slowly Healing of compound fractures and infected fractures is also slow Another important factor is the type of fracture Repair of a long spiral fracture with considerable periosteal involvement requires approximately 6 to 8 weeks while union of a horizontal fracture usually occurs within 10 to 12 weeks (*Piulachs* 1963)

A gap especially if due to continued traction between the fragments is an important cause of non union A gap of more than 0 5 cm prolongs the healing time to 12 to 18 months and if the gap is more than 1 cm healing will require 18 to 24 months (*Urist et al* 1954)

As stated by *Watson Jones* (1963) the most important factor to

---

[1] Present address Servicio de Cirugia Ortopedica Hospital del Sagrado Corazón Borrell 303 Barcelona 15 Spain

avoid delayed union and so reduce the risk of non union is good immobilization of fragments Adequate immobilization of the fragments is therefore necessary to prevent rotational and angular strains at the site of the fracture

The role played by the fibula in delayed union and non union of the tibia has long been known *Irigoyen Dotti* (1966) mentions that one of the causes of delayed union is the diminished pressure between the fragments the influence of the interosseus membrane and the persistence of a non fractured fibula or a fibula that healed within the usual time *Blumenfeld* (1947) quotes that in thirty two (55 2 per cent) of fifty eight cases of non union of the tiba seen at Iowa University Hospital the fibula was intact

Many procedures and treatments for non united fractured tibiae include osteotomy to improve the position of the tibial fragments (*Campbell* 1963) or to allow the fragments to come into contact It is used together with bone graft *Beck* multiple drilling etc In some departments in specific cases of simple transverse fracture of the tibia with intact fibula the fibula is fractured before application of the plaster to allow better contact of fragments (*Palazzi* 1966)

As stated above a gap between the fragments retards union The intact fibula of an adult being stronger than the fibula in a child acts as an internal splint and may therefore prevent approximation of the fragments and thereby delay healing *Pulachs* (1963) said the deleterious influence of an intact fibula is not only because it prevents longitudinal pressure at the fracture site but also because it allows sliding movements thus interfering with healing and consolidation and later in order to help longitudinal pressure on the lower limb it is advisable to apply a walking plaster and if the fibula is healed or was never broken and due to the fact that because of its elasticity prevents good contact of fragments it is necessary to section it It would thus appear that if the fibula is also fractured weight bearing in a walking plaster would promote union of the fragments but if the fibula is intact it would appear advisable to resect the fibula to allow good contact between the fragments

The overall incidence of delayed union and non union has been estimated at less than 3 per cent for the skeleton as a whole (*Owen* 1934) but in the tibia it can be as high as 7 per cent for selected non comminuted fractures (*White et al* 1953) 9 per cent for unselected consecutive cases (*Kuntzmann et al* 1957) and 75 per cent for displaced compound comminuted fractures (*Carpenter et al* 1952)

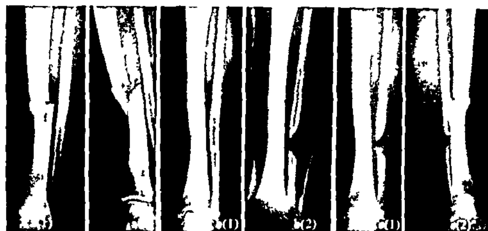
It is important to differentiate delayed union from non union or pseudoarthrosis Though it is not possible to draw a sharp line of distinction between these two conditions union may be regarded as delayed when callus formation fails to occur within the usual time In delayed union the healing process is still active and in non union reparative cellular activity has ceased Therefore in delayed union surgical intervention on the fibula alone may promote healing but in the case of a non union in which the healing process has ceased it is necessary to operate on the tibia at the site of the fracture Treatment of stabilized pseudoarthrosis should so to say reproduce the conditions prevailing shortly after the fracture in order to restart the healing process This can be done either by freshening of the bone ends and resection of fibrous tissue and sclerotic bone or according to *Judet et al* (1965) by osteo-periostic decortication with or without freshening since freshening is secondary in importance (*Palazzi* 1966) Therefore *once the non union is stablished a procedure limited to the fibula is* bound to fail Thus in delayed union if contact between the fragments can be obtained by intervention on the fibula without direct operation on the tibia this procedure would appear to be the one of choice

INDICATIONS

Some signs of union should normally be demonstrable within 6 to 8 weeks If the fibula alone has by then united it can probably prevent union of the tibia Delayed healing of a tibial fracture in the presence of an unfractured or healed fibula appears to indicate resection of the fibula before non union is established

In delayed union the fracture line is still roentgenographically demonstrable initially there is no gap between the fragments no cavitation of the bone ends and no sclerosis but later the fracture line widens with the formation of a hazily outlined cavity and the bone ends are decalcified Union is still only delayed Once non union has been established the surface of the ends of the fracture fragments are well defined smooth and sclerotic Clinically when there is mobility at the fracture site without pain on pressure or swelling of soft tissues this indicates that healing has ceased and therefore this is not delayed union but non union If there is mobility but pain and oedema there is *still some activity and union is still only delayed*

Excision of fibula alone in the treatment of delayed union of the tibia does not appear to have been widely reported in the literature



Figures 1a(1) and 1a(2) Case No 7 P.D Original anteroposterior and lateral X rays of this patient's comminuted fracture of the middle of the tibia and lower third of the fibula caused by fall of a heavy weight on his left leg (19 March 1958)

Figure 1b(1) Anteroposterior X ray on 8 October 1958 (after 29 weeks) of the fracture just before the operation

Figure 1b(2) Anteroposterior X ray on 4 November 1958 after excision of one and a half inches of the fibula

Figures 1(c) and 1c(2) Anteroposterior and lateral X rays on 3 December 1958 7 weeks after the operation The fracture is healed radiographically as well as clinically

Alistair Morrison (1966) used such treatment in two unpublished cases of Law Hospital Carluke Scotland One of the patients was a 60 year old man with a comminuted fracture of the upper left tibia and fibula originally treated by open reduction and screwing After 16 weeks of delayed union two inches of the fibula were excised and union occurred within 10 weeks The other patient was an 80 year old man with an oblique fracture of the upper third of left tibia and fibula His general condition was very poor and the fracture was treated by immobilization in plaster After 24 weeks two inches of the fibula were excised and 8 weeks later the fracture was united

Urist et al (1954) reports three cases of a long oblique saw cut or resection of the fibula performed to allow closure of a gap in the tibia after 8 11 and 18 months of non union in the hope that this would permit the muscles forces to compress the ends of the fragments together In all three cases the fibula healed within 4 weeks while the fracture of the tibia remained non united and a bone graft was performed 4 to 18 months later He concludes that there is no proof that this



Figures 2a(1) and 2a(2) Case No 8 A.S Original anteroposterior and lateral X rays on 25 April 1958 after a motorcycle accident showing the comminuted fracture of the middle of the left tibia and fibula.

Figure 2b(1) Anteroposterior X ray on 30 September 1958 showing the screw and state of the fracture before excision (23 weeks after admission)

Figure 2b(2) Anteroposterior X ray on 29 October 1958 after operation

Figures 2c(1) and 2c(2) Anteroposterior and lateral X rays on 15 December 1958 The fracture was then clinically and radiographically healed (9 weeks after the operation)

procedure is sufficient by itself to produce union of an non united tibia

Fibular resection is NOT treatment for non union of the tibia but only to accelerate healing when union is delayed

CASES AND TECHNIQUE OF OPERATION

This paper reviews fourteen cases of resection of the fibula carried out from 1952 to 1965 at Bridge of Earn Hospital because of delayed union of tibial fractures All fourteen patients were males Of the fourteen fractures 8 were compound 10 comminuted and in 2 cases the fibula had only a crack (Figures 1 and 2)

The operation was performed through a longitudinal lateral incision exposing the fibula subperiosteally The fibula was resected at a level below that of the tibial fracture the fibula being more readily accessible in its lower third Two to three inches of the fibula were excised Resection was preferred to osteotomy because of the possibility of osteotomy s healing too rapidly Postoperatively the leg was immobilized in a midthigh plaster cast and weight bearing was not allowed for 10 to 14 days As soon as the wound had healed weight bearing in a walking plaster was allowed to promote good contact between the ends of the fracture fragments

Initials and age	Date and type of original injury	Date and type of initial treatment	Subsequent treatment
1) T M 21	18 April 1952 Compound fracture midshaft right tibia and fibula with loose fragments anteriorly	18 April 1952 Toilette and suture Insection of Steinman s pins above and below the fracture. Manipulation and plaster of Paris	Series of plasters. Fibula healed in J
2) C.A 27	17 July 1954 Compound fracture midshaft right tibia and fibula with butter fly fragment mid tibia Involvement of tibial vessels suspected	22 July 1954 Toilette Internal fixation with 2 screws Plaster of Paris	Series of plasters. 1 April 1955 Fibrous tissue fro fracture site and screws removed. A freshening cancell chips were packed. Plaster of Paris. Fib healed on 30 Aug 1
3) J H 48	20 May 1955 Comminuted compound transverse fracture upper shaft right tibia and fibula	20 May 1955 Toilette and suture Manipulation and plaster of Paris	Series of plasters. Fibula united on 29 September 1955.
4) R.M. 51	7 January 1956 Compound comminuted midshaft right tibia and fibula with longi tudinal crack running down distal fragment of tibia	7 January 1956 Toilette and suture Steinman s pins above and below fracture Manipulation and plaster of Paris.	Series of plasters. Fibula united on 7 May 1956
5) G M 64	2 August 1957 Compound comminuted fracture middle shaft tibia with double frac ture upper and lower fibula.	2 August 1957 Toilette and suture Steinman s pins above and below fracture Manipulation and plaster of Paris.	Series of plasters. Fibula united on 20 November 1957

Number of weeks without union	Excision of fibula	Date of union	Remarks
41 weeks (9 months and 2 weeks)	30 January 1953 Half an inch of lower third of fibula	1 April 1953 9 weeks (2 months)	
4 weeks (1 year 9 months and 2 weeks)	9 May 1956 One inch of lower third of fibula	26 June 1956 7 weeks (1 month and 3 weeks)	Fell again and refractured tibia on two further occasions on 22 October 1956 and 28 April 1957 Had a sliding graft in October 1956 In April treated with plaster of Paris until 9 October 1957
weeks (3 months)	19 January 1956 Three inches of lower middle fibula	13 April 1956 12 weeks (2 months and 3 weeks)	Refractured tibia on 30 April 1956 Plaster of Paris until 29 June 1956
weeks (7 months and 1 week)	17 August 1956 One inch of lower middle fibula	5 Nov 1956 11 weeks (2 months and 3 weeks)	
weeks (3 months and 1 weeks)	26 November 1957 Two inches of lower third of fibula	26 Febr 1958 13 weeks (3 months)	Had a caliper until 6 August 1958

Initials and age	Date and type of original injury	Date and type of initial treatment	Subsequent treatment
6) J G 34	13 November 1958 Compound fracture lower right tibia and fibula	13 November 1958 Toilette removal of 2 loose pieces of bone and suture Manipulation and plaster of Paris	Series of plasters. Fibula united on 4 Februar 1959 Series of plasters Doubtful non union 13 July 1959
7) P D 41	19 March 1958 Comminuted fracture midshaft of left tibia and lower shaft of fibula undisplaced	19 March 1958 Manipulation and plaster of Paris	Series of plasters. Fibula united on 1 September 1958
8) A.S 26	25 April 1958 Comminuted fracture lower midshaft of left tibia and fibula	25 April 1958 Manipulation and plaster of Paris	29 April 1958 Open reduction and screwing Fibula healed on 17 July 1958
9) J A S 43	28 December 1958 Compound fracture right tibia and fibula.	28 December 1958 Toilette and suture Manipulation and plaster of Paris.	Series of plasters. 13 January 1961 Bone grafting with cancellous bone. Wound infection developed and lasted some months.
10) P M. 48	5 August 1959 Oblique fracture middle third of right tibia and fibula.	5 August 1959 Open reduction and internal screw fixation Plaster of Paris	Series of plasters. Fibula healed on 21 December 1959

(cont)

of weeks without union	Excision of fibula	Date of union	Remarks
weeks months)	15 May 1959 Half an inch of middle fibula	---	The second operation is not a straight forward fibular resection alone and was accompanied by bone chip graft on tibial fracture site Done in doubtful non union At the end of treatment the leg was three quarters of an inch short.
weeks months)	17 July 1959 One and a half inches of middle fibula Through other incision the fibrous bone ends were removed as well as sclerosis Packing of tibia with bone chips	19 October 1959 13 weeks (3 months)	
) weeks 6 months and ² weeks)	14 October 1958 One and a half inches of lower fibula.	3 December 1958 7 weeks (1 month and 3 weeks)	
4 weeks 5 months and 3 weeks	14 October 1958 One and a half inches of lower fibula. Removal of the screw from tibia through *other incision*	15 Dec. 1958 9 weeks (2 months)	
41 weeks ? years 8 months nd ? waeeks	14 September 1961 One inch of lower fibula	14 Dec 1961 13 weeks (3 months)	Continued on plaster for another month because of previous history of infection and length of delayed union
weeks months)	2 Februar 1960 One inch of lower fibula Removal of screw from tibia through other incision	13 April 1960 10 weeks (2 months and 2 weeks)	

Ta

Initials and age	Date and type of original injury	Date and type of initial treatment	Subsequent treatment
11) D B 26	22 April 1962 Fracture middle shaft left tibia and upper shaft left fibula	27 April 1962 Open reduction and tibia plated Plaster of Paris	Series of plasters.
12) D B 25	26 February 1964 Compound fracture lower third of left tibia and fibula	26 February 1964 Toilette and suture. Manipulation and plaster of Paris	Series of plasters.
13) B S 32	10 April 1964 Transverse fracture lower third of tibia with undisplaced crack of fibula	10 April 1964 Plaster of Paris	Series of plasters.
14) D A 18	5 May 1965 Fracture lower third right tibia and fibula Fracture shaft right femur	5 May 1965 Kuntscher nail to femur Steinman s pins above and below fracture Manipulation and plaster of Paris	Series of plasters. 20 October 1965 Bone graft operatio[illegible] on tibia (Bone sla[illegible] and marrow packed

RESULTS

In all fourteen cases the fracture consolidated within 18 weeks (4 months)

Of the fourteen cases

Five healed between 1 and 2 months (three in 7 weeks and two in 0 weeks)

Seven healed in 2 to 3 months (one in 10 weeks two in 11 one in 12 and three in 13 weeks—one of these three after a second excision

(cont)

Number of weeks without union	Excision of fibula	Date of union	Remarks
7 weeks (3 months and 4 weeks)	17 August 1962 One inch of lower fibula. Through anterior incision the plate was removed and the fracture site drilled.	19 Dec. 1962 18 weeks (4 months)	Not a straight forward resection because of drilling Had a below knee walking caliper until 18 March 1963
8 weeks (4 months)	30 June 1964 One inch of lower fibula	26 October 1964 17 weeks (3 months and 4 weeks)	
1 weeks (2 months and 3 weeks)	30 June 1964 One inch of lower fibula	7 weeks (1 month and 3 weeks)	Had a fall on 30 October 1964 sustaining a fracture of anterior lip left lower articular tibia that resulted in an anterior subluxation of the talus leading to ankle arthrodesis on 21 September 1965
2 weeks (7 months and weeks)	17 December 1965 Two inches of lower fibula.	2 March 1966 (2 months and 3 weeks)	

because there was no definite improvement in healing two months after the first operation

One healed between 3 and 4 months (17 weeks)

One healed in 4 months (18 weeks)

These fractures would perhaps have healed with prolonged probably markedly prolonged immobilization in plaster without resection of the fibula

After resection of the fibula the tibial fractures healed between 7 and 18 weeks later It is therefore obvious that this operation hastens tibial

union Resection should perhaps have been done somewhat earlier Generally speaking it would appear that if radiography 6 to 8 weeks after the fracture shows that union is delayed resection of the fibula is indicated

Fibular resection avoids the definite risk of long immobilization in plaster possibly with stiffness of the joints requiring mobilization after the fracture has healed as well as long impairment or loss of healing capacity and not to mention the extra costs of treatment

SUMMARY

1 The importance of an intact fibula in delaying union of tibial fractures is emphasized

2 The theory of excision of 2 to 3 inches of the fibula to allow adequate contact between the ends of the fracture fragments impaction and better contact of the fragments to accelerate healing is set forth and a survey of the literature is given

3 Fourteen cases of such an operation because of delayed union of fractures of the tibia are reported and discussed

4 The results of this procedure showed that all fractures healed within 7 to 18 weeks after the operation was performed

5 In delayed union of fractured tibiae if impaction of the fragments can be obtained by acting on the fibula without direct operation on the tibia this procedure would appear to be the one of choice On this basis, resection of a portion of the fibula should be considered as a simple but effective measure at quite an early stage in treatment

RESUME

1) L importance d un perone intact en cas de non soudure d une fracture du tibia est soulignee

2) La theorie de l excision de quelques centimetres du perone pour provoquer le collapsus du niveau de la fracture tibiale afin d obtenir une impaction et un meilleur contact des fragments dans l espoir d accelerer le moment de la guerison est exposee et il est donné un compte rendu de la litterature

3) Quatorze cas d operation pour union differée de fractures du tibia sont expliques et discutes

4) Les resultats de cette methode montrent que toutes les fractures ont eté gueries dans l espace de 7 a 18 semaines apres l operation

5) Dans les cas de non soudure d une fracture du tibia si l on peut obtenir l impaction des fragments en agissant sur le perone sans operation directe du tibia cette methode apparaitra comme une des meilleures Sur cette base la resection d une partie du perone peut etre consideree comme un moyen simple et efficace a un stade precoce du traitement

ZUSAMMENFASSSUNG

1) Die Wichtigkeit einer intakten Fibula bei verzogerter Weilung von Tibiabrüchen wird hervorgehoben

2) Die Theorie der Exzision von 2 bis 3 Zoll der Fibula um ein Zusammensinken auf der Hohe des Tibiabruches und eine Zusammenstauchung mit besserem Kontakt der Fragmente mit der Hoffnung auf eine Verkürzung der Heilungszeit zu gestatten wird besprochen und eine Übersicht der Literatur wird durchgegangen

3) Vierzehn Fälle dieser Operation verzogerter Heilung von Tibiabruchen werden erklart und besprochen

4) Die Ergebnisse dieses Vorgehens zeigten dass alle Brüche im Zeitraume von 7 bis 18 Wochen nach Ausfuhrung der Operation heilten

5) Bei verzögerter Heilung von Tibiabruchen wenn Zusammenstauchung der Fragmente mittels Operation aus der Fibula ohne direkten Eingriff an der Tibia erreicht werden kann scheint dieses Vorgehen die Methode der Wahl zu sein Auf dieser Grundlage sollte die Resektion eines Teiles der Fibula als eine einfache aber effektive Massnahme bereits in einem fruhzeitigen Stadium der Behandlung angesehen werden

ACKNOWLEDGEMENT

I wish to acknowledge the help and criticism of Prof. *I S Smillie* and Mr *C S Campbell* and to thank all the staff of the X Ray II Department and the Orthopaedic Office Bridge of Earn Hospital, for the search of X rays and case notes

REFERENCES

1 Blumenfeld Isidoro (1947) Pseudo arthrosis of the long bones. *J Bone Jt Surg* 29 97-106

2 Campbell (1963) Operative Orthopaedics 4th Ed. C. V Mosby Comp St. Louis Vol 1

3 Carpenter E. B., Dobble J J & Siewers, C. F (1952) Fractures of the shaft of the tibia and fibula Comparative end results from various types of treatment in a teaching hospital. *Arch Surg* 64 443-456

4 Irigoyen Dotti L. (1966) Pseudoartrosis retardo de consolidacion y perdida de substancia osea en las fracturas diafisarias de la tibia Tratamiento *Rev Ortop Traum Lat Amer* 11 147–152
5 Judet R Judet J et Coll (1965) La decortication ostéopériosteé principe technique indications et resultats *Mem Acad Chir* 91 463–470
6 Kuntzmann J & Meyer J (1957) *A propos du traitement des fractures de jambe.* Etude clinique de 200 cas suivis *Rev Chir Orthop* 37 224–249
7 Morrison Allstair Personal communication
8 Owen H R (1932) *The problem of delayed union and ununited fractures. Ann Surg* 95 759–7,0
9 Palazzi A Santos Personal communication
10 Piulachs Pedro (1963) Lecciones de Patologia Quirurgica Tomo II 1 parte 2 Ed Editorial Toray S A Barcelona
11 Urist Marshal R. Mazet Jr Robert & McLean Franklin C (1954) Pathogenesis and treatment or delayed union and non union A survey of 85 ununited fractures of the shaft of the tibia and 100 control cases with similar injuries *J Bone Jt Surg* 36 A 931–967
12 Watson Jones Reginald (1963) Fractures y Traumatismos Articulares. 2 Edic Espanola Reimpresion Salvat Ed S A Barcelona
13 White J H & Earley N W (1953) Screw stabilization in fractures of the tibial shaft *J Bone Jt Surg* 35 A 749–755

Acta orthop scand 40 119–121 1969

From the Department of Orthopaedic Surgery University of Goteborg Sweden

SIMPLE CONTROL DEVICES IN EARLY AMBULATION FOLLOWING SURGERY OF LOWER LIMBS

By

Carl Hirsch & Elisabet Lewenhaupt

Received 25.xi 67

The general policy of orthopaedic departments is early ambulation provided the injured or reconstructed area can tolerate the forces coming into play when the patient is out of bed In this connection the term "non weight bearing" is often employed meaning that the patient should not be allowed to touch the floor with his foot But non weight bearing does not exclude forces coming into play by muscle action often increased by leverage for instance in the upper and lower parts of the femur However if the foot is resting on the floor while the body weight is carried by crutches or canes several advantages will be achieved Leg muscles can be allowed to rest or function with a smaller load The patient will be able to control his position far better and will much quicker learn to move about This is especially helpful for aged people

With very simple devices we have been using a training program showing the patient how he should practice getting used to cane walking The foot of the affected side stands on a balance the normal one on a wooden plateau Figure 1 The patient being instructed how to use the canes during walking will feel how much weight he can place on the less weight bearing side and adjust himself to the instructions given by the physiotherapist Figure 2 and Figure 3 The gait can then be checked if necessary by using a more sophisticated electronic walkway for further control Figure 4 Although the walkway is part of our research equipment the simple balance devices have given our physiotherapists a very reliable tool with which they can follow the instructions of the orthopaedic surgeon when he is anxious to curtail the patient s stay in bed

Figure 1



Figure 2



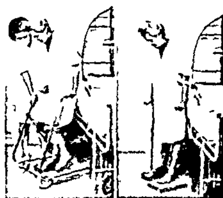


Figure 3



Figure 4

SUMMARY

A simple device recording decrease of weight bearing during walking consisting of a commercially available balance and a wooden plateau is illustrated It has been proved to be most helpful in instructing the patient at the time of ambulation

RESUME

Illustration d un simple procede enregistrant moins le poids porte pen dans la marche et se composant d une balance et d un plateau en bois que l on peut trouver dans le commerce Il s est avere que cet instrument est de la plus grande aide pour l instruction des malades au moment de l ambulation

ZUSAMMENFASSUNG

Eine einfache Anordnung die verminderte Gewichtsbelastung beim Gehen registriert und aus einer im Handel erhältlichen Waage und einem hölzernen Plateau besteht wird illustriert Sie hat sich als aus serst behilflich bei der Belehrung des Patienten zur Zeit des Verum gehens erwiesen

Acta orthop Scandinav 40 122-129 1969

From the Department of Orthopaedic Surgery (Head Anders Hulth MD)
Malmo General Hospital University of Lund Malmo

AGE AND SEX INCIDENCE OF ANKLE FRACTURES

By

Bo E R Nilsson

Received 1 ix 67

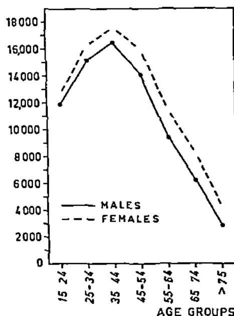
Bruns (1882) was the first to demonstrate the influence of age on the production of fractures More recent studies indicate (*Buhr & Cooke* 1959 *Alffram & Bauer* 1962 *Alffram* 1964) that while certain injuries at least in adults, are caused mainly by trauma, other injuries to the skeleton such as fracture of the forearm and of the upper end of the femur are apparently related to the endogenous factors of age and disease These studies have formed a basis for further research with the prevention of fractures as an ultimate goal

In fractures of the ankle joint the mechanics of the causative trauma have been studied The information obtained from such studies has greatly improved the treatment of these injuries The objective of the present study however was to describe the age and sex incidence of fractures of the ankle joint particularly with reference to fracture patterns indicating endogenous causes of fracture

MATERIAL AND METHODS

The data in this study were obtained from a clinical follow up of 717 fractures of the ankle joint diagnosed in the Department of Radiology at the General Hospital, Malmo All the individuals over fifteen years of age and residents of Malmo were included. As practically all the roentgendiagnostic work on traumatic cases in Malmo is carried out in this hospital the figures arrived at are very close to the absolute numbers of diagnosed fractures in the city Age and sex specific incidence was then calculated on the basis of the population of Malmo (Figure 1)

The study covered largely the time period during which the data of *Alffram & Bauer* (1962) and *Alffram* (1964) were obtained from the very same population (Figures 2 and 3)



1 *Age and sex distribution of the population of Malmo*

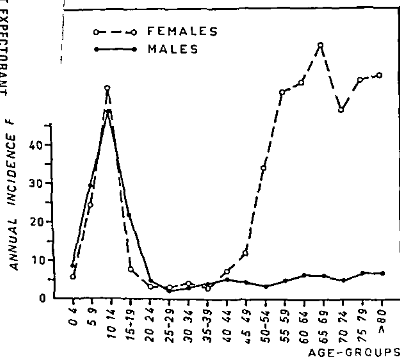


Figure 2 Age and sex incidence of fractures of the distal end of radius and/or ulna (Alffram & Bauer 1962)

17 SATURDAY OCTOBER 1970
ZEET EXPECTORANT for coughs and colds

Acta orthop Scandinav 40 122-129 1969

From the Department of Orthopaedic Surgery (Head Anders Hulth M D)
Malmo General Hospital University of Lund Malmo

AGE AND SEX INCIDENCE OF ANKLE FRACTURES

By

Bo E R Nilsson

Received 1 ix 67

Bruns (1882) was the first to demonstrate the influence of age on the production of fractures More recent studies indicate (*Buhr & Cooke* 1959 *Alffram & Bauer* 1962, *Alffram* 1964) that while certain injuries at least in adults are caused mainly by trauma other injuries to the skeleton such as fracture of the forearm and of the upper end of the femur are apparently related to the endogenous factors of age and disease These studies have formed a basis for further research with the prevention of fractures as an ultimate goal

In fractures of the ankle joint the mechanics of the causative trauma have been studied The information obtained from such studies has greatly improved the treatment of these injuries The objective of the present study however was to describe the age and sex incidence of fractures of the ankle joint, particularly with reference to fracture patterns indicating endogenous causes of fracture

MATERIAL AND METHODS

The data in this study were obtained from a clinical follow up of 717 fractures of the ankle joint diagnosed in the Department of Radiology at the General Hospital Malmo All the individuals over fifteen years of age and residents of Malmo were included As practically all the roentgendiagnostic work on traumatic cases in Malmo is carried out in this hospital the figures arrived at are very close to the absolute numbers of diagnosed fractures in the city Age and sex specific incidence was then calculated on the basis of the population of Malmo (Figure 1)

The study covered largely the time period during which the data of *Alffram & Bauer* (1962) and *Alffram* (1964) were obtained from the very same population (Figures 2 and 3)

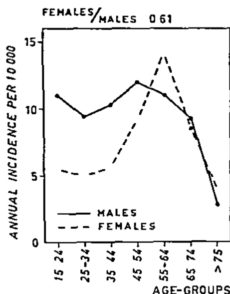


Figure 4 Age and sex incidence of fractures of the ankle joint (total material 717 fractures)

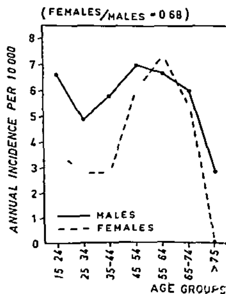


Figure 5 Age and sex incidence of fractures of the l[illegible] (414 fractures)

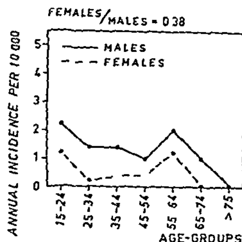


Figure 6 Age and sex incidence of fractures of the medial malleolus only (73 fractures)

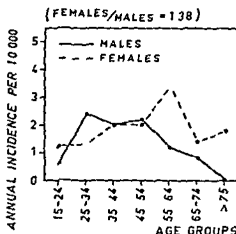


Figure 7 Age and sex incidence of fractures of the posterior tibial process isolated or combined with other fractures of the ankle joint (143 fractures)

of fracture of the forearm There are two possible explanations of this phenomenon the risk of adequate trauma may be less in older age because of the generally changed behaviour of the elderly and common causes of fracture such as stumbling while running downstairs bicycle accidents and sports injuries all accidents that may provide the adequate type and degree of trauma are less common in the elderly In addition changes of the strength of the ligaments may influence the fracture pattern The Venn-diagram in Figure 10 attempts to demon

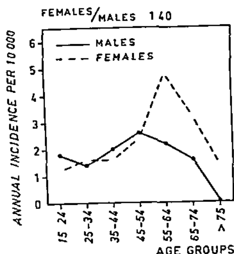


Figure 8 Age and sex incidence of bi and trimalleolar fractures of the ankle joint (170 fractures)

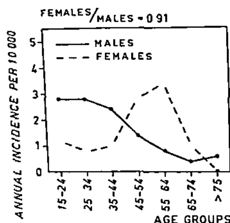


Figure 9 Age and sex incidence of ligamental rupture in the bone attachment only (143 fractures)

strate the interaction of adequate trauma weakness of the bones and strength of the ligaments in the production of fracture of the ankle joint A and C is a common combination in young males A B and possibly C together cause the raise of incidence in middle aged females while the elderly usually retain only the variable B which is usually not sufficient by itself to cause fracture Figure 9 shows the incidence

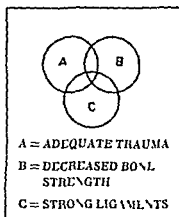


Figure 10 Venn diagram of possible factors influencing the production of fractures of the ankle joint

of ligamental rupture in the bone attachment The peak value in the middle aged women remains largely unchanged, while the incidence of this injury appears to drop in males earlier than observed in other fracture types This may indicate a decreasing strength of the ligaments and a decreasing influence of factor C

SUMMARY AND CONCLUSIONS

The age and sex specific incidences of fractures of the ankle joint suggest a strong influence of changes of the bone quality with age particularly in females In older ages groups these injuries are rare probably because of decreased risk of adequate trauma and because of changes in the quality of the ligaments

RESUMÉ

L incidence de l age et du sexe sur l articulation de la cheville semble indiquer que l âge a une forte influence sur les modifications de la qualité des os en particulier chez les femmes Dans le groupe très âgé ce genre de lésions sont rares probablement par suite d un moins grand risque des traumas qui les provoquent et aussi par suite des changements dans la qualité des ligaments

ZUSAMMENFASSUNG

Das Auftreten von Knochelbrüchen spezifisch fur Alter und Geschlecht legt den Gedanken eines starken Einflusses von Veranderungen der

Knocheneigenschaften mit dem Alter besonders bei Frauen nahe In vorgeschritteneren Altersgruppen sind diese Schäden wahrscheinlich wegen des geringeren Risiko fur ein adequates Trauma und wegen Ver anderungen der Eigenschaften der Ligamente selten

REFERENCES

Alffram P A & Bauer G C H (1962) Epidemiology of fractures of the forearm. A biomechanical investigation of bone strength *J Bone Jt Surg* 44 A 105

Alffram P A (1964) An epidemiologic study of cervical and trochanteric fractures of the femur in an urban population *Acta orthop scand* Suppl 65

Bauer G C H (1960) Epidemiology of fracture in aged persons A preliminary investigation in fracture etiology *Clin Orthop* 17 219

Bruns P (1882) Die allgemeine Lehre von den Knochenbruchen *Dtsch Chirurgie* 27 part 1 Ferd Enke Stuttgart

Buhr A J & Cooke A M (1959) Fracture patterns. *Lancet* i 531

Acta orthop Scandinav 40 130 136 1969

From the Orthopaedic Hospital Aarhus Denmark
(Head Professor Lavind Thomasen M D)

EPIPHYSEODESIS AND EPIPHYSEAL STAPLING ON THE LOWER LIMBS

By

Hans Hostrup & Søren Pilgaard

Received 14 1 68

The object of the present paper is to submit an analysis of the results of growth inhibiting operations done on the lower limbs at the Orthopaedic Hospital Aarhus during the period 1950–1959 inclusive Two methods were used, the one described by *Phemister* in 1933 and *Blount s* from 1949 Epiphyseal stapling was not used as a temporary growth inhibiting procedure (*Nordentoft* 1964) It seems reasonable to compare the two methods The calculated correction (*Green & Anderson* 1957) was related to the obtained correction Primary and secondary complications as well as the number of corrective procedures are reviewed and compared with the results of others (*Nordentoft* 1964 *Pilcher* 1962 and *Trias et al* 1961)

The cause of growth inhibition in a paralysed limb has not been elucidated A relationship is assumed to exist between the degree of shortening and the age at onset of paralysis, moreover the extent of the paralysis seems to influence the consequent difference in limb length (*Stinchfield et al* 1949)

MATERIAL

During the period 1950–1959 a total of 98 patients were treated 41 girls and 57 boys The preoperative diagnoses were Sequelae of poliomyelitis in 81 cases unilateral shortness of a lower limb in 6 while 11 patients exhibited the sequelae of various conditions as congenital deformities osteomyelitis spastic hemiparesis and burns Analysis of the group of 81 polio patients with a view to the influence of the age at onset of polio upon the shortening gave the following results (when excluding 6 patients for whom the age at onset was unknown)

No of pts	Age at polio	Average shortening	Average age at measurement
25	0–1 yr	5 2 cm (2 6–8 3 cm)	11 7 yrs (8–16 yrs.)
24	1–2 yrs	5 3 cm (1 7–8 6 cm)	11 7 yrs (10–14 yrs)
20	2–6 yrs	4 9 cm (3 1–8 6 cm)	11 6 yrs. (10–13 yrs)
6	over 6 yrs	3 1 cm (? 0–4 5 cm)	13 2 yrs. (12–15 yrs)

We did not find a consistent relationship between the degree of paralysis and its localization in the legs on the one hand and the shortening on the other There might be considerable shortening of the thigh although the paralysis affected the leg below the knee

Number of patients who primarily had a Blount operation	53
Number of patients who primarily had the Phemister operation	38
Number of patients who primarily had Blount as well as Phemister operation	7

RESULTS OF BLOUNT OPERATION

In addition to the 53 patients this group includes the 7 patients who also had the Phemister operation at the same time upon another epi physis These patients are included and so are their complications if any if they were due to the Blount procedure In these 60 patients operations were done on 69 epiphyses 46 times on the proximal tibial epiphysis and 23 times upon the distal femoral epiphysis

Primary operative complications occurred in 6 patients (10 per cent) viz in 3 cases wound infection in 1 restricted movements of the knee and in 2 transient paresis of the peroneus In 16 cases displaced gap ing or broken staples constituted a secondary complication

CORRECTIVE PROCEDURES

In 12 cases (20 per cent) re operation had to be done because of asym– metrical growth in the stapled epiphysis These procedures were per- formed 1–5 years after the primary operation—because of varus or valgus deformity of the tibia The corrective procedures consisted in 5 cases in Phemister epiphyseodesis done twice on one patient in 3 cases in repeated epiphyseal stapling by the Blount method and in 4 cases in osteotomy on the tibia

SUPPLEMENTARY OPERATIONS

In 10 cases (16 6 per cent) re operation had to be done because of in sufficient growth inhibition In 3 cases a Phemister procedure was done

on the same epiphyseal plate supplemented by operation on another epiphyseal plate In 7 cases operation was done on another epiphyseal plate twice by the Blount method and 5 times by the Phemister method In 3 cases the staples were removed after the primary operation as they were causing complaints

FOLLOW-UP

Fifty patients were seen after cessation of growth The follow up examination included in 43 instances radiological spot measurement of the lower limbs This measurement had also been done preoperatively In 38 cases the skeletal development had been determined prior to the operation by means of the *Greulich Pyle atlas* (1950) This showed the skeletal age to range from 9 5 to 13 5 years average 10 9

At clinical follow up 16 patients (32 per cent) had recurvation of the operated knee In 14 instances there was a recurvation of 5–10 while in 2 the recurvation was 20 A varus or valgus deformity was found in 8 cases (16 per cent) The deformity was in one case only so pronounced that the patient wished corrective surgery but this was not felt to be indicated

On an average the obtained correction was 2 0 cm maximum 7 3 and minimum —5 2 The cause of the failing effect in this last mentioned patient is not known The operation was performed on the distal femoral epiphysis, but the inequality in leg length increased quite uninfluenced by the operation 65 2 per cent of the cases showed a residual difference in leg length of —2 cm to + 1 2 cm as over correction was found to have occurred in two The remaining 18 had a difference exceeding 3 cm maximum 11 4 cm

RESULTS OF PHEMISTER OPERATION

38 patients had primary operation by this method To this group should be added the 7 patients who had both types of operation The operation was done on a total of 58 epiphyses in 13 cases on the proximal tibial epiphysis and in 15 on the distal femoral epiphysis Primary operative complications occurred in 2 cases (4 4 per cent) viz 1 case of transient peroneal paresis and one case of transient restriction of knee movement

CORRECTIVE PROCEDURES

Owing to asymmetrical growth 3 patients were treated (6 7 per cent) These operations were done 1–2 years after the primary operation In

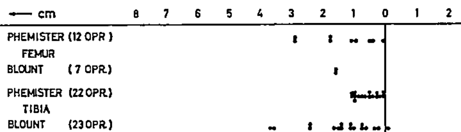


Figure 1 Difference between calculated and obtained correction

2 cases the procedure consisted in tibial osteotomy and in one case in a Phemister re operation

SUPPLEMENTARY OPERATIONS

Due to deficient growth inhibition re operation had to be done on 2 cases (4 4 per cent) In both instances the Phemister operation was done on another epiphyseal plate Both operations were carried out one year after the primary operation

FOLLOW UP

Thirty one patients were seen after cessation of growth In 30 spot measurement was done prior to the operation and at follow up In these cases the operation had been done at a skeletal age which according to *Greulich & Pyle* s atlas (1950) ranged from 10–14 years average 12 1 years

Four patients exhibited recurvation of the operated knee In 3 of these patients there was also mild varus deformity The recurvation was negligible in 3 (5 5 and 10) while one patient had a varus deformity so severe that osteotomy was done In another 2 cases there was mild varus deformity

The average correction was 2 7 cm In 71 2 per cent there was a residual inequality in leg length of —3 to +2 cm as over correction had resulted in 3 cases

COMPARISON OF CALCULATED WITH OBTAINED CORRECTION

On the basis of their material *Green & Anderson* (1957) worked out curves which form the basis of a calculation of the approximate equalization obtainable These curves were used in the treatment of the

present material The relationship between the obtained and the calculated corrections is shown in Figure 1 If more than one operation had been done, the figures are calculated on the basis of the most recent one This calculation includes only cases in which radiological measurement was done preoperatively as well as after cessation of growth

DISCUSSION

The presupposition of satisfactory correction is approximate accuracy in predicting the extent of the growth inhibition obtainable by the operation To this end the authors used *Green & Anderson s* (1957) curves and determination of skeletal age on the basis of *Greulich & Pyle s* atlas (1950) Operations were done on a total of 127 epiphyses Over correction resulted in 5 cases in 2 after the Blount and in 3 after the Phemister operation

Primary operative complications were few and negligible, and less common after the Phemister than after the Blount operation On the other hand the frequency of asymmetrical growth after these operations cannot be disregarded This occurred especially after the Blount operation 20 per cent requiring re operation because of asymmetrical growth in the stapled epiphysis According to the present study of patients whose growth had been completed the Phemister operation seems to be preferable

Hogberg & Lidstrom (1957) arrived at the same conclusion in their follow up on a material which had also been treated by both methods Nevertheless they advise the Blount operation as they had a larger number of deformities requiring operative correction after the Phemister operation

In a discussion on a paper by *Brockway et al* (1954) *Blount* (1954) pointed out that the complications of the Blount procedure are due to erroneous technique and can therefore be avoided In our material recurvation was fairly common and may be attributed to incorrect placement of the posterior staples Dilatation and rupture of the staples must be due to faults in the material of which they are made

SUMMARY AND CONCLUSION

During the period 1950-1959 a total of 98 patients were treated for shortening of one lower limb so marked that it required operation by the method of Blount or Phemister on the unaffected limb Of these

patients 81 were seen after cessation of growth Primary complications were few and negligible The late complications of the two types of operation are described Corrective and supplementary operations were commonly done after the Blount operation The calculated correction is compared with the correction obtained at cessation of growth The results of the Phemister operation were somewhat better than those of the Blount operation

RESUME

Entre 1950 et 1959 98 malades ont ete traites pour un raccourcissement d un membre inferieur si marque qu il fallut une operation d apres la methode de Blount ou de Phemister pour le membre non atteint Sur ces malades 81 ont ete reexamines apres la cessation de la croissance Les complications primaires furent peu nombreuses et negligeables Les complications tardives apres ces deux types d operation sont decrites Des operations correctives et complementaires ont habituellement ete pratiquees apres l operation par la methode de Blount La correction calculee est comparee avec la correction obtenue a la cessation de la croissance Les resultats obtenus par l operation de Phemister ont eté quelque peu meilleurs que ceux par l operation de Blount

ZUSAMMENFASSUNG

Wahrend des Zeitraumes 1950–1959 wurde eine Gesamtzahl von 98 Patienten wegen Verkurzung der unteren Gliedmasse behandelt die so ausgesprochen war dass sie eine Operation nach der Methode von Blount oder Phemister an der nichtbetroffenen Gliedmasse erforderte Von diesen Patienten wurden 81 nach dem Wachstumabschluss ge sehen Primare Komplikationen waren wenige und gering Die spätcn Komplikationen beider Operationstypen werden beschrieben Korri gierende und erganzende Operationen wurden gewöhnlich nach der Blount Operation ausgefuhrt Die berechnete Korrektur wird mit der Korrektur die man beim Wachstumsabschluss erhielt verglichen Die Ergebnisse der Operation nach Phemister waren etwas besser als die nach der Blount schen Operation

REFERENCES

1 Blount W P & Clarke G R (1949) Control of Bone Growth by Epiphyseal Stapling J Bone Jt Surg 31 A 464
2 Blount W P (1954) Discussion J Bone Jt Surg 36 A 1068

3 Brockway A., Craig W A & Cockrell B R. (1954) End Result Study of Sixty Two Stapling Operations *J Bone Jt Surg* 36 A 1063
4 *Green W T &Anderson M. (1957) Experiences with epiphyseal arrest in correcting discrepancies in length of the lower extremities in infantile paralysis. J Bone Jt Surg* 39 A 853
5 Greulich W W & Pyle I (1950) Radiographic Atlas of Skeletal Development of the Hand and Wrist Oxford University Press.
6 *Hogberg N & Lidstrom A (1957) Aspects of epiphysiodesis Acta orthop scand* 27 60
7 Nordentoft, E. L. (1964) *Den operative epifyseodese* Munksgaard *Copenhagen.*
8 Phemister D P (1933) Operative Arrestment of Longitudinal Growth of Bones *in the Treatment of Deformities J Bone Jt Surg* 15 1
9 *Filcher M I (1962) Epiphyseal Stapling Thirty Five Cases Followed to Maturity J Bone Jt Surg* 44 B 82–85
10 Stinchfield A J Reidy J A & Barr J S (1949) Prediction of unequal growth *of the lower extremities in anterior poliomyelitis J Bone Jt Surg* 31 A *478*
11 Trias A Mueller K & Ray D R. (1961) Epiphyseal Stapling *Surg Gynec Obstet* 113 314

Acta orthop Scandinav 40 137-14? 1969

From The Department of Orthopaedic Surgery (Head Anders Hulth M D)
Malmo General Hospital, University of Lund Malmo Sweden

THE INFLUENCE OF A HIGH FLUORIDE CONTENT IN THE DRINKING WATER ON THE BONE MINERAL MASS IN MAN

By

P A ALFFRAM J HERNBORG & B E R NILSSON

Received 7 xi 6?

In recent years numerous studies have indicated a beneficial effect of fluoride administration on the bone mineral mass in man *Berstein et al* (1966) demonstrated in a large population study an increased bone density in subjects from areas with a high fluoride content in the drinking water

The objective of the present study was to evaluate the influence of a high fluoride intake with the drinking water on the bone mass of the peripheral skeleton in healthy women

MATERIAL AND METHODS

In the city of Malmo in southern Sweden the fluoride content of the drinking water is 0 2-0 4 ppm.[1] Sixty two healthy women forty five to seventy two years old were selected from the population of Malmo (Control Group)

In the town of Billesholm, located less than fifty miles from Malmo the fluoride content of the drinking water is 4 0-6 8 ppm. Forty seven healthy women were selected from the population of Billesholm (Fluoride Group)

None of the subjects selected had a history of fracture of the measured limb of endocrinous disease back ache or deformity There were no racial or ethnical differences between the two populations nor were there any obvious differences in the dietary habits The average time elapsed after menopause was slightly but not significantly longer in the Fluoride Group To qualify for this study at least twenty years of residency in the area was required. One third of the Fluoride Group were born and raised in the town of Billesholm another third had spent forty years or more in the area.

The evaluation of the bone mass was based on three measurements 1) The com

[1] Parts per million

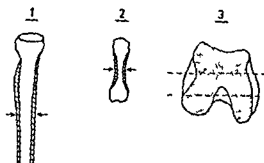


Figure 1 Evaluation of bone mass
1 The combined cortical thickness of the radius
2 The combined cortical thickness of the second metacarpal
3 The mineral content of the distal end of femur

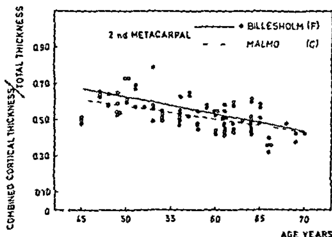


Figure 2 The relationship of combined cortical thickness of the second metacarpal and age

bined thickness of the two cortici measured with a calliper on antero posterior radiograms of the second metacarpal (Figure 1 2) (*Nordin* 1961) The values were expressed as fractions of the total thickness of the metacarpal. 2) The combined thickness of the cortici on antero posterior radiograms of the proximal end of the radius (*Meema* 1963) (Figure 1 1) The values were expressed as fractions of the total thickness of the radius. 3) The density of the distal end of the femur was evaluated from the attenuation of a photon beam passing through the femur laterally in the epicondylar area. The method has been described by *Nilsson* (1966) (Figure 1 3)

The exposure of the radiograms the measurements of the cortical thicknesses and the measurements of the femur densities were all performed in a standardised way in the same hospital The film object distance was about sixty four cm

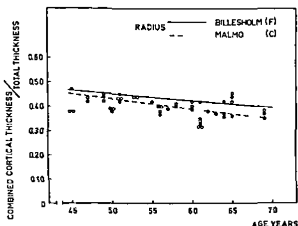


Figure 3 The relationship of combined cortical thickness of the radius and age

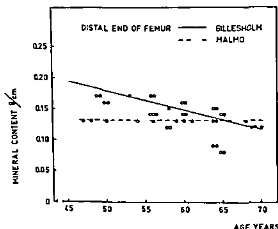


Figure 4 The relationship of the mineral content of the distal end of the femur and age

RESULTS

The various parameters of skeletal mass were more or less dependent on age in both groups (Figures 2 3 and 4) The regressions of age and bone mineral mass were compared by covariance analysis (Table) In none of the comparisons were very high levels of probability obtained All the parameters do however indicate the same tendency and if the data are taken together it may be concluded that the bone density was greater in subjects from the area with a high water fluoride content

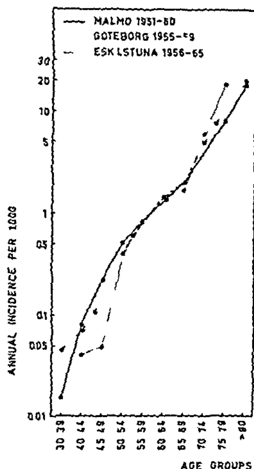


Figure 5 Incidence of fracture of the upper end of femur in three Swedish cities with varying fluoride concentrations in the drinking water

Table Analysis of covariance levels of probability

Treatment		Scatter	Slope	Intercept
Age vs	Bone Mass Radius	1 > 0 9	P > 0 2	0 05 > P > 0 01
Age vs	Bone Mass 2 Metacarp	P > 0 2	P > 0 2	0 2 > P > 0.1
Age vs	Bone Mass Distal Femur	0 2 > P > 0 1	0 1 > P > 0 05	0 9 > P > 0 1

There was no relationship between the time of residency in Billesholm and the bone density of the fluoride group

DISCUSSION

It has previously been demonstrated (*Bernstein et al* 1966) that the incidence of radiologically decreased density of the lumbar vertebrae is lower in a population with an increased intake of fluoride with the drinking water The findings in the present study indicate a similar difference in the bone mineral mass of the peripheral skeleton of healthy women

From the two studies it should be possible to conclude more definitely that a high fluoride concentration in the drinking water is associated with an increase of the skeletal mass and that this increase is not likely to be confined to certain geographical regions or anatomical locations *Bernstein et al* (1966) also demonstrated a decreased incidence of vertebral compression fractures in their population with a high fluoride intake In epidemiological studies of the incidence of fracture of the upper end of the femur in three cities in Sweden by *Alffram* (1964) in Malmo (0 2–0 4 ppm) by *Martensson* (1962) in Gothenburg (<0 1 ppm) and by this group (1967) in Eskilstuna (0 8–1 2 ppm) (Figure 5) no significant differences could be demonstrated Thus the water fluoridation level usually recommended for the prevention of dental caries (1 ppm) does not to a significant degree influence the incidence of fracture of the upper end of the femur

SUMMARY

The bone mass was evaluated in sixty two female residents in an area with a low fluoride content in the drinking water and in forty seven female residents of an area with a high water fluoride content The measurements represented the skeletal mass of the limbs The skeletal mass was demonstrated to be greater in residents of the high fluoride area

REFERENCES

Alffram P A (1964) An epidemiologic study of cervical and trochanteric fractures of the femur in an urban population *Acta orthop scand* Suppl 65

Barnett, E. & Nordin B E. C. (1961) The clinical and radiological problem of thin bones. *Brit J Radiol* 34 683

Bernstein D S Sadowsky N., Hegsted D M Curl C.D & Slare F S (1966) Prevalence of osteoporosis in high and low fluoride areas in North Dakota. *J Amer Med Ass* 198 499

Meema H E. (1963) Cortical bone atrophy and osteoporosis as a manifestation of aging *Amer J Roentgenol* 89 1287

Mårtensson L. (1962) Är svensk sjukhusplanering ändamålsenlig? Statistiska undersökningar rörande collumfrakturens frekvens *Sv Läk Tidn* 59 3195

Nilsson B E. R (1966) Post traumatic osteopenia A quantitative study of the bone mineral mass in the femur following fracture of the tibia in man using Americium 241 as a photon source *Acta orthop scand* Suppl 91

Acta orthop Scandinav 40 143–152 1969

From the Department of Orthopaedic Surgery University of Goteborg Sweden
(Head Prof Carl Hirsch, M D)

THE PRESENCE OF NERVES IN ORIGINAL AND REGENERATED SYNOVIAL TISSUE IN PATIENTS SYNOVECTOMISED FOR RHEUMATOID ARTHRITIS

By

IAN GOLDIE & MARK WELLISCH[1]

Received 25 x 67

INTRODUCTION

Joint pain is one of the cardinal symptoms of rheumatoid arthritis The exact origin of this has yet to be explained Cartilage has despite the destruction it undergoes in this disease been ruled out as it does not contain neural elements (*Miller & Kasahara* 1963) In bone however nerves are frequently found According to *Miller & Kasahara* (1963) they are intimately involved in the endosteum of the medullary trabeculae They also occur in the Haversian Canals as shown by *Milgram & Robinson* (1966) in a study on adult dogs Since the osseous compartment of the joint may become part of the disease in rheumatoid arthritis it may well be a site for pain Finally the soft tissues surrounding the joint i e fibrous capsule and mesenchymal linings are richly supplied with nerve elements which may conduct pain (*Gardner* 1950 *Barnet et al* 1954 *Polacek* 1961 *Hirsch et al* 1963) The fibrous capsule contains both capsulated and unencapsulated complex and free nerve endings which are believed to be pressure sensitive and responsible for stereotactic and movements sensibility like *e g* the Ruffini Vaer Paccinian and Golzi Mazzoni endings (*Boyd* 1954 *Skoglund* 1956 *Eklund et al* 1960 *Lundberg et al* 1960 The mesenchymal lining which is the synovial tissue contains nervous elements which are very scarce (*Gardner* 1950 *Barnett et al* 1961) in contrast to the richly endowed fibrous capsule There is some disagreement whether these

[1] Research Fellow University of California Los Angeles National Health Institute

synovial nerve fibres are afferent but it is agreed that they are unmyelinated probably autonomic associated with blood vessels (*Gardner* 1950 *Barnett et al* 1961) *Kellgren & Samuels* (1950) nevertheless believe that synovial tissue contains afferents a conclusion reached in a study on synovial sensitivity at arthrotomy in local anesthesia Certain indications point to the synovial tissue carrying some of the responsibility for the articular pain in rheumatoid arthritis First it is a target tissue of the disease with an inflammatory infiltration of lymphocytes plasma cells and phagocytes and fibrinous exsudate (*Norton & Ziff* 1966) the latter of which is believed to be pain producing Second most often pain and other joint symptoms disappear for a variable length of time after synovectomy By this procedure part of the target tissue of the disease is removed and thereby also nervous elements whereby a partial denervation ensues Certain indications suggest that decrease in pain may be due to desensitization After synovectomy the regenerated tissue appears with the same pathomorphological elements as prior to surgery (*Goldie* 1967) within the same time limit as normal regeneration Nerves do not appear within the same short time period Also some disease activity remains as in a number of synovectomised cases the antiagglutination factor (AAF) is positive and elevated in joint fluid whereas it remains negative in serum (*Goldie* 1967) Nerve endings have not been encountered in these cases

The regeneration of synovial tissue after synovectomy is a well established fact (*Key* 1923, *Lindström* 1963 *Marmor* 1966 *Whitefield & Stevens* 1966 *Goldie* 1967) So far however no reports have been encountered which describe the presence of nerve elements in regenerated synovial tissue The object of this study has therefore been to demonstrate the presence of nerves in synovial tissue removed at synovectomy for rheumatoid arthritis and in regenerated synovial tissue at later arthrotomy or biopsy not less than one year and not more than three years following the first synovectomy

MATERIAL AND METHODS

27 patients with well established signs of rheumatoid arthritis were selected for this study Tissue samples were taken from three sources first from patients undergoing synovectomy for the first time in an affected joint second, from patients who had undergone synovectomy from one to three years previously and who now volunteered for a second arthrotomy (total 12 of which 10 free of symptoms) third from patients who had earlier undergone synovectomy and who now submitted themselves for biopsy with a Parker Pearson Synovial Biopsy Needle (*Par*

ker & Pearson 1963) Original tissue was studied in 15 specimens 13 of which were obtained from knee joints one from elbow and one from wrist Regenerated tissue was obtained in 12 patients of which 8 at arthrotomy of knee joints and 4 by Parker Pearson biopsy of knee joints

All tissue samples were submitted to the Pathology Department for pathomorphologic verification of the type of the tissue and diagnosis The specimens were stained according to the intravital methylene blue technique and 6 according to the Gros Bielschowsky silver impregnation method. The methylene blue technique was chosen because of its relative simplicity and its value in staining for nerve fibres and endings in a wide variety of tissues as shown by *Coers & Wolf* 1959 *Hirsch et al* 1963 *Miller et al* 1963 and *Goldie* 1964 One of the advantages with this technique is its employment of whole pieces of tissue which permits observation of nerve fibres in a three dimensional plane in translucent specimens

Intravital Methylene Blue Staining

Fresh specimens are immersed in 0 005 per cent methylene blue in normal saline acidified to a pH of about 3 5 for 30–45 minutes (depending on size of sample) at room temperature (18–20 C) Then gentle rinsing in phys saline for 10 minutes and oxidized for 10 minutes on a dampened piece of gauze in room air The specimens are then fixed in 8 per cent ammonium molybdate for 8–12 hrs at 8–10 C. Then rinsed in running tap water for 1¼-2 hrs and dehydrated in 96 per cent alcohol for 2 hrs Before placing in the alcohol the specimens are flattened between two microscope slides held together with paper clips Final dehydration in 100 per cent alcohol for 2 hrs and then removed from slides and placed in Xylene for clearing When cleared storing in benzyl benzoate in which medium the specimens are suspended during microscopic examination

Gros-Bielschowsky Staining as Modified by Coers & Wolf 1959

The sections are placed in distilled water for an hour and are then transferred to 10 per cent silver nitrate for forty five minutes They are then placed without washing in 20 per cent formalin filtered after being neutralized with magnesium carbonate The solution is changed when it becomes cloudy After fifteen minutes the sections are washed for a few seconds in two changes of distilled water and placed in a Petri dish containing the following ammoniacal silver solution To 30 ml. of 20 per cent aqueous silver nitrate concentrated ammonia is added drop by drop until the resultant brown precipitate disappears after which a further 15 drops may be added if the sections darken too rapidly but this is not usually necessary The sections are examined under the microscope whilst still in the solution and are left in the latter until impregnation of the terminal porti n of the nerve fibres has occurred. If this is not achieved within a few hours a drop of the 20 per cent formalin solution may be added and diffused by blowing on the surface of the silver solution This may be repeated at 15 minutes intervals The secti ns must be removed before a precipitate forms or when impre nati n is complete and placed successively in each of the following solutions 20 per cent aque us ammonia, distilled water 1 per cent aqueous acetic acid distille l w ter 0 02 per cent

aqueous yellow gold chloride (half one minute) The sections are then washed in distilled water dried on albuminized slides dehydrated cleared and mounted in the usual way

RESULTS

The methylene blue stain is not specific for nerve fibres as reticulin and capillaries also take the stain Moreover this may accumulate in folds of the specimen which may make the interpretation deceptive Nerve fibres appear as thin slender filaments of 1-3 microns with irregularly placed nodules along their course Often they accompany a vessel or may be lodged in the wall of the same The conclusive evidence is the termination into any of the types of nerve endings described below

Capillaries are as a rule easily recognised as the endothelial cells take the stain and give the appearance of ghosted blue cells with a deeply stained nucleus Reticulin fibres and folds generally appear as broken up uneven and coiled strands the irregular course of which leave an impression of complete disorganisation

The nerve endings encountered are of the free fibre ending type which terminate as single branches complex unencapsulated endings which appear as complexly branched and encapsulated endings which look like small bulbs

In the original synovial tissue endings of the free fibre type and complex unencapsulated could be identified The free fibre endings were seen as single branches tapering off either into a thin filament or into the appearance of a string of pearls (Figure 1) Branched filaments with tapered tips were observed (Figure 2) Verification of these observations was obtained in the Gros Bielschowsky stain Other methods as *e g* the cholinesterase technique were not utilized in this particular study

In regenerated synovial tissue nerve fibres and endings identical to those found in the original tissue were observed (Figures 3 4) The timelag of one to three years after synovectomy did not seem to have any influence on the presence of nerves

COMMENT

Some limitations follow the use of the methylene blue staining technique which have become obvious in this investigation

First pieces of extirpated tissue were used which differs from the procedure of *Loers & Wolf* (1959) and *Miller & Kasahara* (1963) who



Figure 1 *Free fibre ending with varicosities No terminal expansions From original synovium Methylene blue* × 200

Figure 2 *Complex unencapsulated nerve ending from original synovial tissue Methylene blue* × 450

injected the stain into intact tissue in situ By not using the injection method an interference with the metabolic activity may arise and a disturbance of circulation in the extirpated tissue samples may ensue which may perhaps make the uptake of stain less than optimal In an immersion study by *Hirsch et al* (1923) on connective tissues especi





Figure 3 Arrow indicating free fibre ending running transversely in regenerated synovial tissue Methylene blue × 200

Figure 4 Complex unencapsulated nerve ending with some expanded terminal tips Regenerated synovial tissue Methylene blue × 400

ally ligamentous capsular and intervertebral disc structures satisfactory results were achieved which no doubt justifies the employment of the method as described

Second in contrast to other investigators techniques (*Hirsch et al* 1963) the specimens in this study were not sectioned The synovial tissue—both original and regenerated—often appears quite translucent

at excision and it was threfore thought not necessary to do any sectioning As the method implies a specific pH (about 3.5) for sectioned material it is conceivable that a divergence from staining our specimens in thin sections might not yield the same results In some samples which were rather large the deepest parts of these did not take up the stain satisfactorily It was believed that by the thickness of specimens the low pH might in some way limit the uptake of the stain Tentatively it was thought that the low pH denatures the proteins on the specimen surface producing a coagulum through which the stain could not penetrate and thus leaving the central interior unstained Therefore different pH values were tested for thick specimens and it was found that staining in pH 7.0 gave a better penetration

Third because of poor penetration of the stain in some specimens which has been discussed above the course of nerve fibres was difficult at times to follow for any distance since they changed depth in the tissue which could reach 3–5 mm s thickness

Fourth because the specimens varied in size from about 5×2 mm to 5×7 mm the times in the staining procedure had to be adjusted empirically to get optimal staining

These limitations make a statement on the density of innervation difficult whereas the presence of neural elements can be proved without greater effort In those cases where some doubt as to the presence of nerves arose verification with the Gros Bielschowsky was obtained

Our results confirm the findings of *Gardner* (1950) and *Barnett et al* (1961) concerning the presence of nerves in original synovial tissues As mentioned nerve endings of various types were encountered It is however difficult to ascertain anything definite concerning the function of these nerves as their size 1–3 μ and difficulty in identification render neurophysiologic investigations difficult These fibres however among other functions seem to play a role in the conduction of pain It has been assumed (*Hirsch et al* 1963) that free fibre endings are associated with pain complex unencapsulated endings with tissue position and encapsulated with pressure perception As in this investigation the different types of nerve endings were observed in the synovial tissues it may be possible that part of the pain experienced in rheumatoid arthritis is transmitted through the free fibre endings On the other hand the surrounding fibrous structures are richly innervated and may either by distension of exsudate or exsudate or by inflammatory oedematous infiltration create pain At synovectomy it is impos





Figure 3 Arrow indicating free fibre ending running transversely in regenerated synovial tissue Methylene blue × [illegible]00

Figure 4 Complex unencapsulated nerve ending with some expanded terminal tips. Regenerated synovial tissue Methylene blue × 4[illegible]0

ally ligamentous capsular and intervertebral disc structures satisfactory results were achieved which no doubt justifies the employment of the method as described

Second in contrast to other investigators techniques (*Hirsch et al* 1963) the specimens in this study were not sectioned The synovial tissue—both original and regenerated—often appears quite translucent

original et regénéré chez les malades souffrant d'arthrite rhumatoïde. A cette fin il a été obtenu des prélèvements de 27 malades souffrant d'arthrite rhumatoïde constatée. Parmi ceux-ci 12 ont volontairement accepté la prise de prélèvements durant une période d'un à trois ans après la synovectomie. 10 d'entre eux n'ont présenté absolument aucun symptôme.

Au moyen des techniques au bleu de méthylène et de Gros Bielschowsky il a été possible de démontrer des structures nerveuses aussi bien dans le tissu synovial original que regénéré. La présence d'extrémités terminales de fibres libres et des extrémités terminales de nerfs complexes sans gaine a été observée. Parmi celles-ci on considère que les premières ont pour mission de conduire la douleur.

ZUSAMMENFASSUNG

Der Zweck dieser Untersuchung ist es gewesen, das Vorhandensein von Nervenfasern und Nervenendigungen in ursprünglichen und regenerierten Synovialgewebe bei Patienten mit chronisch rheumatischer Polyarthritis nachzuweisen. Aus disem Grunde wurden Proben von 27 Patienten, alle mit sicherer Polyarthritis rheumatica, erhalten. Von diesen unterwarfen sich 12 der Probenentnahme ein bis drei Jahre nach der Synovektomie. 10 waren vollständig symptomfrei.

Mittels Methylenblau und Gros Bielschowsky Technik war es möglich Nervengebilde sowohl im ursprünglichen als auch im regenerierten Synovialgewebe nachzuweisen. Das Vorhandensein von Nervenfasern im regenerierten Gewebe konnte ein Jahr nach der Synovektomie festgestellt werden. Freie Faserendungen und nichteingeschlossene Nervenendungen wurden beobachtet. Von diesen werden die ersteren als schmerzleitend angesehen.

REFERENCES

Barnett, C. H., Davies, H., Mac Conaill & Thomas, C. C. (1961) Synovial joints. New York.

Boyd, I. A. (19 4) Histological structure of receptors in the knee joint of the cat correlated with their physiological response. *J Physiol* 124 4;6

Coers, L. & Wolf, A. L. (1959) The innervation of muscle, Blackwell, Oxford.

Efskind, L. (1941) Anatomy and physiology of the joint capsule. *Acta orthop scand* 12 214

Eklund, G. & Skoglund, S. (1960) On the specificity of the Ruffini like joint receptors. *Acta physiol scand* 49 184

Gardner, E. (1950) Physiology of movable joints. *Physiol Rev* 30 127–1 6

Goldie, I. (1967) Data to be published

localisation of vascular changes is most irregular (*Brånemark et al* 1963 (6)). Difficulties may also arise in identifying healed lesions.

The irregularity of vascular changes has been studied by *Virtama* (1959). In an arteriographic study at autopsy of ten cases of rheumatoid arthritis he found in the digital arteries of the hand local obliterations of the arterial trunks especially in the vicinity of the affected joint spaces, local poststenotic shuttle-like dilations of the arteries, hypervascularisation and dilation of the arterioles close to erosions of bone.

The changes encountered are proliferative with a marked cellular infiltration in and around the vessel wall of lymphocytes and small mononuclear cells (Figure 1). Deposition of fibrinoid substance in the vessel wall is common (*Kulka* 1959 (5)). Destructive changes may also be seen such as necrosis, thrombosis, aneurysm formation and invasion of neutrophils. These features are indicative of the fulminant malignant form of rheumatoid arthritis.

In extensive investigations on the microvascular derangement in synovial tissues in rheumatoid arthritis *Kulka* (1959 (5), 1966(7)) concludes that there is a segmental angiopathy which particularly involves the venules and capillaries. Larger vessels may nevertheless become engaged and the angiopathy can appear without relation to other lesions. The most pronounced effect following this angiopathy is exudation and ischaemia. According to *Kulka* (1959 (5)) the angiopathy in slowly progressing cases is indistinguishable from secondary forms of vascular involvement occurring in any other chronic inflammatory process. The angiopathy is regarded as a primary manifestation in rheumatoid arthritis with a particular predilection for venules which become obliterated by necrosis and fibrin impregnation or by endothelial proliferation.

Observations have been made by *Kulka* (1959 (5)) in a rheumatoid nodule of one day's duration. The venules in this exhibited an intense inflammatory reaction and an escape of eosinophilic material could be shown which had a delicate reticular structure typical of inflammatory fibrin. In this region of fibrin deposition localised to the perendothelial zones necrosis of leukocytes was observed.

Besides the above mentioned changes including fibrinoid necrosis of the vessel wall and vascular obliteration *Kulka* (1966 (7)) has also described varying degrees of venular and capillary dilation as well as exudative leakage.

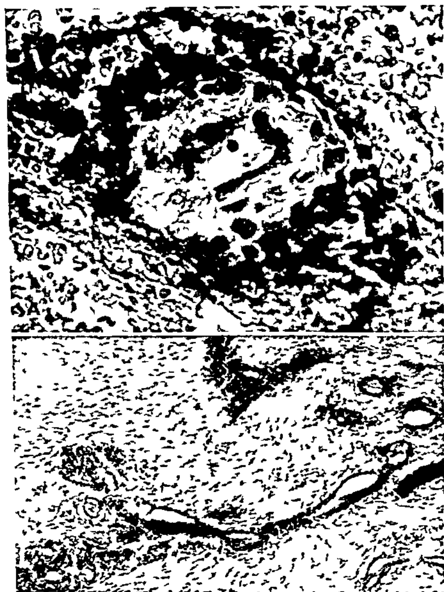


Figure 1 a. Synovial tissue from knee joint in rheumatoid arthritis Proliferative changes with marked lymphocytic and mononuclear infiltration around arteriolar wall × 640

Figure 1 b Same as in 1 b but venules which are slightly dilated × 640

VASCULAR CHANGES IN VITAL MICROSCOPY

Using vital microscopic techniques *Brånemark et al* (1963 (6)) carried out *in vivo* investigations of synovial tissues in human knee joint exposed at operation. They found that tissue adjacent to a synovial tissue with old rheumatic changes may have a capillary system which appears quite normal in structure and function.

The venules of the rheumatic tissue exhibited dilation and varying caliber which resulted in an uneven outline and tortuosity and slow almost stagnated blood flow. Arteriolar venular shunts at the basis of synovial capillary loops were observed.

In summary it then appears that light microscopic investigations have yielded information about the vascular pathology of synovial tissues in rheumatoid arthritis that indicate an angiopathy of varying intensity. Arterioles, venules and capillaries become involved to varying degrees.

The information thus obtained has of late become further expanded on and also scrutinized with the development of more refined methods such as electron microscopy.

VASCULAR CHANGES IN ELECTRON MICROSCOPY

In 1961 Hirohata & Kobayashi carried out an electron microscopic study on biopsies from 11 joints with rheumatoid arthritis. They found that many factors are involved in the vascular changes of rheumatoid arthritis. In vessels less than 10 μ in caliber there is an increase in the height of the endothelial cells and several cytoplasmic processes extend into the vascular lumen occasionally causing an obstruction. In the exudative phase of rheumatoid arthritis the endothelial cells of arterioles and venules become flattened and their cytoplasm becomes bright. A swelling of mitochondria is noted and small vacuoles appear in the endothelial cells. The intercellular space between the endothelial cells becomes widened and the basement membrane turns thicker though in places disruptions are noted. There is an atrophy of the muscle cells in the arterioles, fibroblasts appear in the tunica media and in the adventitia there is a marked hyperplasia of the fibers. In the exudative phase leukocytes, lymphocytes, monocytes and plasma cells are found at the basal surface of the endothelial cells and in the adventitia perivascular cells and collagen fibers are noted.

In chronic cases *Hirohata & Kobayashi* describe numerous cytoplasmic processes extending into the lumen from the endothelial cells and



Figure 2 Electron micrograph from normal synovial tissue showing a longitudinally cut venule containing a granulocyte and several erythrocytes The endothelium is generally rather thin but thickens in the nuclear region (upper right corner) Outside the endothelium several layers of basement membranes and periendothel al cell processes are seen —Magnification × 9 000



Figure 3. *Electron micrograph from normal synovial tissue showing a transversely cut capillary. The lumen is very narrow and almost filled by a red blood cell. The endothelial lining of the capillary is thin except for the region occupied by the endothelial cell nucleus (N). Outside the endothelium a periendothelial cell ([illegible]) and several basement membranes are seen. – Magnification × 13 000*



Figure 4 Electron micrograph from [illegible] tissue showing a detail of a capillary wall. Outside the thin endothelium there are several concentrically arranged basement membranes of a [illegible] varying thickness. Only a small portion of pericytal cell seen as (PC) is found in this section.
Magnification × 48,000



Figure 5. Survey electron micrograph from normal synovial tissue showing a part of a venule wall. Note the thick, partly split endothelial basement membrane. Magnification × 14 000

pinocytosis is seen. The mitochondria of the endothelial cells decrease in number and become swollen and filaments appear in the cytoplasm.

According to these authors the inflammation commences in the endothelial cell and is then spread to the tunica media and tunica externa.

In an electron microscopic investigation on synovial tissues in rheumatoid arthritis *Norton & Ziff* (1966 (9)) devoted their main interest to the cellular components but some mention is made of the vascular appearance. They conclude that apart from a certain hypertrophy of connective tissue elements about blood vessels, there is little evidence that the vascular bed is characteristically changed in rheumatoid arthritis.

At a recently held symposium on early synovectomy in rheumatoid arthritis *Ball* (1967 (10)) in summary of the works of *Barland, Novikoff & Hamerman* (1964 (11)), *Wyllie, Haust & More* (1966 (12)) and *Norton & Ziff* (1966 (9)) stated that electron microscopic studies (mainly based on the relatively late stages?) leave the question of a specific structural target within the synovium unanswered.

At the same symposium *Paul* (1967 (13)) maintained that in rheumatoid disease vasculitis, segmental or focal, is a hallmark of the disease. Arteritis and arteriolitis occur most often in advanced or highly active disease. The most significant type of vascular involvement, however, is the venulitis and capillaritis. The endothelial cells of the minute vessels display hypertrophy and proliferation with numerous filopodia



Figure 6 Electron micrograph showing a detail of the endothelial cell in Figure 4 The cytoplasm contains several mitochondria (M) a well developed Golgi apparatus (G) a few pinocytotic vesicles and numerous ribosomes (R) C denotes a centriole The arrow marks a cell junction —Magnification × 36 000

The subject of vascular pathology in rheumatoid arthritis thus becomes most controversial in view of which method is used for investigation To further elucidate this problem we have pursued an electron microscopic study on the vascular appearance in normal synovial tissues and in cases of rheumatoid arthritis



Figure 7. Electron micrograph showing another detail of the endothelial cell in Figure [illegible]. The most characteristic components of the cytoplasm in this section are bundles of thin filaments. This part of the cell also contains numerous pinocytotic vesicles. Magnification × [illegible]8 000.



Figure 8 Electron micrograph from normal synovial tissue showing a part of capillary wall The endothelium (E) is extremely thin in some areas (arrows) but there are no true discontinuities —Magnification × 47 000

MATERIAL AND METHODS

Synovial tissue was obtained at synovectomies for rheumatoid arthritis in knee joints in 15 cases All of these patients had suffered from their disease for more than five years and been subjected to various conservative treatments without any obvious improvement On macroscopic examination at synovectomy the synovium was glossy and congested hyperemic and coated with fibrin studded with hypertrophic villi often with necrotic tips The articular cartilage was in all cases destroyed in a patchy way and numerous erosions filled with granulation tissue were present along the bone cartilage borders In most cases only remnants of the menisci remained and the cruciate as well as the collateral ligaments were lax In all cases an excessive exudate was present. Arthrotomy for investigative exploration was done in 3 cases As nothing abnormal was noted in either macroscopic or microscopic appearance of the synovial tissue this served as normal material Specimens were prepared for electron microscopy as described below The specimens from rheumatoid arthritis were subjected to light microscopic study in order to ascertain that changes were present in this tissue which in general are accepted as being compatible with the described pathomorphology in rheumatoid arthritis.

For electron microscopy small pieces of synovial tissue were excised and immediately immersed into a fixative consisting of 3 per cent glutaraldehyde buffered at pH 7 2 by sodium cacodylate Two hours later the tissue pieces were transferred to a second fixative containing buffered 1 per cent osmic acid. After postfixation for 1 5–2 hours the tissue was dehydrated in ethanol and embedded in Epon The sectioning was performed on an LKB Ultrotome and the electron microscopical examination in a Siemens Elmiskop I.

OBSERVATIONS AND DISCUSSION

The tissues obtained from the cases of rheumatoid arthritis were studied in the light microscope with special attention to the appearance



Figure 9 Electron micrograph from normal synovial tissue showing part of venule wall The endothelial cell contains several dense bodies which might be lysosomes Magnification × 42 000

of the vessels The changes observed confo[illegible] with those described by *Kulla* (1959) No certain abnormalities [illegible] in the [illegible]erioles The venules were dilated and congested [illegible] by small clouds of extravasated er[illegible] [illegible] lar infiltration around many [illegible] es an [illegible] tion was intramural Fibrin



Figure 10 Electron micrograph of a capillary in synovial tissue from a case of rheumatoid arthritis This survey picture does not disclose any abnormalities of capillary structure—Magnification × 11 000

tered deposits both in vessel walls and extravascularly. Similar changes, though more discrete, were noted in capillaries.

A thorough knowledge of the normal ultrastructure of a tissue is a prerequisite for judging pathological changes in the same. Most reports on ultrastructural changes of synovial vessels in rheumatoid arthritis lack information about the normal ultrastructure of these vessels. Consequently long series of features have been described as pathological although they may in reality be normal. In this study the electron microscopical structure of capillaries and venules was assessed in normal synovial tissue as a background for evaluating the observations made in rheumatoid arthritis.

The ultrastructural appearance of the normal synovial capillaries and venules is greatly varying with respect to both the thickness and structure of the wall and the size and shape of the lumen. The height of the endothelial cells varies extensively from vessel to vessel and also between different portions of the same vessel. The thinnest parts of the endothelial lining measure only a few hundred Å, while the thickest portions, generally the nuclear region where the bulk of the cytoplasm is found, can be several microns thick. The luminal surface is sometimes rather smooth but as a rule it is furnished with a varying number of projections of various size and shape. The cell membranes of adjacent endothelial cells are always closely apposed and often equipped with desmosomes. The cytoplasm always contains pinocytotic vesicles, but the number of these structures is extremely varying. Mitochondria and endoplasmic reticulum as well as free ribosomes exhibit no deviations from what is known and described about small vessels in other tissues. The most characteristic cytoplasmic component is a well developed system of thin filaments. These filaments, which have a diameter of about 70 Å, are arranged in bundles. The bundles have a wavy course and occupy a considerable part of the cytoplasm. Some endothelial cells contain numerous dense, rounded or elongated bodies which could represent lysosomes. Such cells are sometimes found in large numbers in a portion of a vessel, while in other portions the cells almost or entirely lack this type of cytoplasmic elements.

Figure 11. Electron micrograph of a venule wall in synovial tissue from a case of rheumatoid arthritis. The lumen is packed by red blood cells. Outside the endothelium (E) there are several layers of pericendothelial cell processes (PC) and basement membranes, just as is found in normal synovial tissue. Magnification × 11 000.



Figure 11

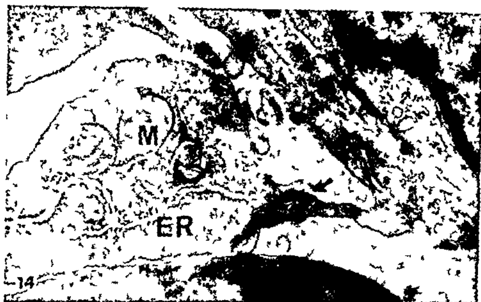


Figure 14 Electron micrograph of a detail of Figure 12 showing the junction of two endothelial cells (arrow) In the cytoplasm mitochondria (M) and endoplasmic reticulum (ER) are the most conspicuous components —Magnification × 37 000

jections are lacking but the basement membranes retained a characteristic pattern is observed of multilayered basement membranes

When studying the ultrastructure of capillaries and venules of synovial tissue in rheumatoid arthritis we found no significant deviation from this normal pattern The endothelial cells are of varying heights just as in the normal tissue and their luminal surfaces are smooth or furnished with projections There is no widening of the intercellular spaces and pores or discontinuities are not observed The endothelial cell cytoplasm contains the same organelles of the same appearance as does the normal cytoplasm The periendothelial structures the basement membranes and periendothelial cells do not exhibit any characteristic changes

---

Figure 15 Electron micrograph of the wall of a synovial venule from a case of rheumatoid arthritis The endothelial cell (E) contains a well developed system of 70 Å filaments and is covered by a basement membrane (BM) In the space between the endothelium and a periendothelial cells process (PC) and between this and another periendothelial cell (PC) are many cross cut collagen fibrils Magnification × 50 000



Figure 1



Figure 16 Electron micrograph of a venule wall in the synovial tissue from a rheumatoid joint The endothelial cytoplasm contains a large number of pinocytotic vesicles Magnification × 40 000

In this context it is important to point out that the sections studied by electron microscopy were all the site of changes estimated as pathologic in light microscopy

Again it must be emphasized that the irregularity with which the disease strikes the target organ may be of some significance in evaluating the observations made by electron microscopy The vessel walls may be sites of characteristic changes which can only be detected by serial electron micrographs along the course of a vessel On the other hand this investigation has revealed that vessels in rheumatoid arthritis which in light microscopy disclose certain features regarded as pathologic demonstrate a variation in structure which is entirely comparable to that we have found in the normal controls

Some ultrastructural features reported by *Hirohata & Kobayashi* (1964 (14)) and *Paul* (1967 (13)) and regarded by them as pathological coincide no doubt with the structural appearance of small vessels of normal synovial tissue The remaining observations such as vacuolization swelling of mitochondria and widening of intercellular spaces may well be explained by an unsatisfactory technique used for the preservation of the tissue

SUMMARY

Light microscopic investigations of the vascular bed in synovial tissues in rheumatoid arthritis have yielded the information that a vasculitis or angiopathy of varying intensity is present Electron microscopic studies have indicated that in rheumatoid arthritis an inflammation commences in the endothelial cells of venules and capillaries and spreads to the tunica media and tunica externa

The present study was carried out on synovial tissue from normal and rheumatoid knee joints Light microscopy of the vascular bed in the rheumatoid synovial tissue revealed inflammatory changes largely corresponding to those described by earlier investigators In order to be able to estimate and characterize these changes at the ultrastructural level we performed a thorough electron microscopical study on the venules and capillaries in normal synovial tissue. When comparing the ultrastructural pattern of these normal vessels with that of the corresponding vessels in the rheumatoid synovial tissue it turned out that no significant deviations could be established

RESUME

Des recherches microscopiques de la couche vasculaire du tissu synovial dans des cas d arthrite rhumatoide ont revele la presence d une vasculite ou angiopathie d une intensite variable Des etudes microscopiques electroniques ont indique que dans l arthrite rhumatoide l inflammation debute dans les cellules endotheliales des vaisseaux et des capillaires pour s etendre ensuite aux revetements median et externe

La presente etude s est basee sur le tissu synovial provenant d articulations normales et rhumatoides du genou La microscopie de la couche vasculaire du tissu synovial rhumatoide a revele des modifications inflammatoires correspondant largement a celles decouvertes par des chercheurs precedents Afin de pouvoir estimer et caracteriser ces modifications au niveau ultrastructural nous avons procede a une etude *microscopique electronique approfondie des vaisseaux et des* capillaires du tissu synovial normal Une comparaison entre le modele ultrastructural de ces vaisseaux normaux et des vaisseaux correspondants du tissu synovial rhumatoide a demontre qu il ne pouvait pas etre etabli de deviations significantes

ZUSAMMENFASSUNG

Mikroskopische Untersuchungen des Gefässbettes von Synovialgewebe in Fällen von rheumatischer Arthritis haben die Kenntnis ergeben, dass eine Vasculitis oder Angiopathie verschiedenen Grades vorhanden ist. Elektronmikroskopische Untersuchungen haben gezeigt, dass beim Gelenkstheumatismus eine Entzündung in den Endothelzellen der kleinen Venen und Kapillaren beginnt und sich zur tunica media und tunica externa ausbreitet.

Die gegenwärtige Studie wurde an Synovialgewebe von normalen und rheumatischen Kniegelenken ausführt. Lichtmikroskopie des Gefässbettes von rheumatischem Synovialgewebe offenbarte entzündliche Veränderungen, die denen von früheren Untersuchern entsprachen. Um im Stande zu sein, diese Veränderungen auf dem ultrastrukturellen Niveau zu beurteilen und zy charakterisieren, führten wir grundliche elektronmikroskopische Untersuchungen der Venulen und Kapillaren von normalen Synovialgewebe aus. Wenn man die ultrastrukturelle Anordnung dieser normalen Gefösse mit der von entsprechenden Gefässen in rheumatischem Synovialgewebe verglich, stellte es sich heraus, dass keine bezeichnenden Abweichungen festgestellt werden konnten.

REFERENCES

1 Cruickshank B (1954) Arteritis of rheumatoid arthritis. *Ann rheum Dis* 13 136

2 Sokoloff L & Bunim J (1957) Vascular lesions in rheumatoid artritis. *J chron Dis* 5 558

3 Schmid F R, Cooper N S, Ziff M & McEwen C. Arteritis in rheumatoid arthritis. *Amer J Med* 30 56

4 Kulka J P, Bocking D, Ropes M W & Bauer W (1955) Early joint lesions of rheumatoid arthritis. Report of eight cases with knee biopsies of lesions of less than one year's duration. *Arch Path* 59 129

5 Kulka, J P (1959) The pathogenesis of rheumatoid arthritis. *J chron Dis* 10 388

6 Brånemark P I, Lindström J, Jonsson I, Laine V & Vainio K (1963) Capillary structure and function in rheumatoid arthritis. A vital microscopic study of conjunctival and surgically exposed joint tissue. *Acta rheum scand* 9 284

7 Kulka J I (1966) Vascular derangement in rheumatoid arthritis. *Modern trends in rheumatology*. Ed Alan Hill. Butterworths

8 Virtama P (1959) Changes of the digital arteries in rheumatoid arthritis. *Acta rheum scand* 5 304

9 Norton W L & Ziff M (1966) Electron microscopic observations on the rheumatoid synovial membrane. *Arthritis Rheum* 9 589

10 Ball J (1967) Rheumatoid synovial pathology Symposium on Early Synovectomy in Rheumatoid Arthritis *I.S.R.A* Amsterdam.
11 Barland P Novikoff A B & Hamerman D (1964) Fine structure and cytochemistry of the rheumatoid synovial membrane with special reference to lysosomes *Amer J Path* 44 853
12 Wyllie J C Haust M D & More R H (1966) The fine structure of synovial lining cells in rheumatoid arthritis *Lab Invest* 15 519
13 Paul W D (1967) Synovectomy of the digital joint of the hand. Symposium on Early Synovectomy in Rheumatoid Arthritis *I.S.R.A* Amsterdam
14 Hirohata K & Kobayashi I (1964) Fine structure of the synovial tissues in rheumatoid arthritis *Kobe J Med Sci* 19 195

Additional references not mentioned in text

Ball J Chapman J A & Muirden K D (1964) The uptake of iron in rabbit synovial tissue following intraarticular injection of iron dextran A light and electron microscopic study *J Cell Biol* 22 351
Bywaters E G L (1957) Peripheral vascular obstruction in rheumatoid arthritis and its relationship to other vascular lesions *Ann rheum Dis* 16 84
Davies, D V & Palfrey A J (1966) *Electron microscopy of normal synovial membrane* Studies on the anatomy and function of bone and joints VIII Ed Evans F G Springer Verlag
Dettmer N & Cotta, H. (1967) Form und Funktionsprobleme an der menschlichen Gelenkkapsel unter normalen und pathologischen Bedingungen *Arch orthop Unfall Chir* 61 104
Kulka J P (1959) The vascular lesions associated with rheumatoid arthritis *Bull Rheum Dis* 19 201
Kulka J P (1966) Microcirculatory impairment as a factor in inflammatory tissue damage *Ann N Y Acad. Sci* 116 1018
Sokoloff L (1963) *The pathophysiology of peripheral blood vessels in collagen diseases The peripheral blood vessels* Ed J L Orbison and D Smith Baltimore Williams & Wilkins

Acta orthop Scandinav 40 176-19? 1969

From the Institute for Experimental Research in Surgery University of Copenhagen

EXPERIMENTAL EPIPHYSEAL INJURIES

Grading of Traumas and Attempts at Treating Traumatic Epiphyseal Arrest in Animals

By

Erik Lossl Nordentoft

Received 18 x 67

Epiphyseal injuries are common in children but seldom cause permanent disturbances of growth except in the case of slipped upper femoral epiphysis which however is usually not of purely traumatic origin

If a young child sustains epiphyseal arrest in one of the rapidly growing growth zones an angular deformity and shortening result if the injury is peripheral in the growth cartilage If the injury is localized centrally only a shortening will result but this shortening may become so severe as to be seriously disabling

At our present stage of therapeutic ability the angulation may be corrected by osteotomy its recurrence may be inhibited by rendering the epiphyseal arrest total and the shortening may be treated by correcting osteotomies *epiphyseodesis or Blount stapling on the other leg* or bandaging However such treatment is often far from rewarding It would be valuable therefore to be able to abolish the inhibition of growth at least in those patients in whom a considerable proportion of the growth cartilage has remained intact

There have been but few clinical reports to elucidate traumatic epiphyseal arrest The explanation is that this injury is relatively uncommon extremely varied and that it is difficult to elucidate its pathogenesis as well as the development of the growth disturbances

Aitken (1936) is usually quoted for his classification of epiphyseal lesions into three types However two of his types which may entail permanent inhibition of growth were based only upon a case *histories*

But while clinical experience is scanty recent years have brought

Aided by a grant from King Christian X Foundation

a number of excellent experimental studies for elucidating the traumatology of the epiphyseal zones

Ford & Key (1956) perforated the epiphyseal cartilage of young rabbits with a one-eighth of an inch drill This did not cause any major shortening in spite of osseous or fibrous bridging between the epi- and metaphysis When larger drills were used the shortening became more marked

Friedenberg (1957) performed major or minor partial resections of the periphery of the growth cartilage and surrounding bone This was invariably followed by osseous bridging through the resected area but in many cases growth continued indicating that the bone bridge must have fractured owing to the pressure of growth

Dale & Harris (1958) carried out manual epiphyseolysis on 80 rabbits The separation always occurred between the growth cartilage and the metaphysis During the first posttraumatic weeks the cartilage increased in height Thereafter enchondral ossification in the metaphysis was resumed and 3 weeks after the trauma any trace of the injury had been obliterated

Campbell et al (1959) resected minor areas of the peripheral growth cartilage and surrounding bone without observing major deformities After they had chiselled off a piece of the epiphyseal growth cartilage and metaphysis they seldom saw retardation of growth if the fragments were reduced immediately But if the fragments were deprived of blood supply or fixed in alcohol permanent inhibition of growth resulted On 15 dogs the metaphysis was resected as far as the metaphyseal limit of the growth cartilage In some cases this resulted in damage to the cartilage and a bony bridge but in most cases there was no or only little retardation of growth When piercing the cartilage with drills of varying sizes they often observed arrested growth after using the larger bore drills

Brashear (1959) creating epiphyseolysis manually on rats observed the same cleavage of separation as other workers except centrally where he frequently saw injury to the germ cell layer and the subepiphyseal bone A small triangular metaphyseal fragment was often avulsed on the compression side and often there were severe pressure injuries in the cartilage on this side Non-penetrating injuries were associated with increased width of the growth cartilage which later resolved either from the metaphysis or around vessels which from the perichondrium had invaded the highly hypertrophic cell columns

After penetrating injuries regeneration had first to take place from the surrounding cells

Attempts at prophylaxis or at treatment of osseous bridging of the epiphyseal plate appear to have been made only by *Key & Ford* (1958) and *Friedenberg* (1957)

Key & Ford tried unsuccessfully to avoid bridging after reimplantation of growth cartilage grafts packing the grafts in bone wax before reimplantation

Friedenberg, resecting major or minor areas of the growth cartilage and surrounding bone filled the resected area with bone wax or methyl metacrylate He also tried resecting a 4 weeks old Phemister epiphyseodesis in a rabbit by filling the defect with bone wax In no case did he succeed in avoiding osseous bridging

The studies mentioned above have predominantly elucidated the histological development in the growth cartilage after trauma No attempts have been made to inflict an epiphyseal injury which without damaging a larger area of the growth cartilage than necessary will cause permanent disturbance of growth with a high frequency

It is apparent from the named publications that the cells in the growth cartilage possess a considerable ability for regeneration after pressure necroses ischaemic necroses and loss of substance This has been confirmed by a number of investigations into vascular disturbances including transplantations of the growth cartilage (*Lacroix* 1951 *Ring* 1955 *Troupp* 1961 *Heikel* 1961) The experimental results are in keeping with clinical experience of Phemister epiphyseodesis in children (*Goff* 1960 *Green & Anderson* 1957 *Nordentoft* 1964)

There is not agreement as to the area of the growth cartilage from which this regeneration occurs *Langenskiold* (1950) believed that an increase in the width of the cartilage is caused by cell division in the central areas while *Lacroix* (1951) felt that regeneration of the cartilage cells takes place from the periphery, due to an accumulation of cells beneath Ranvier's perichondrial groove *Rigal's* contention that growth in width takes place by interstitial cell division is compatible with the findings of *Brashear* (1959) *Heikel* (1961) and *Troupp* (1961)

It must be considered an established fact that premature arrest of longitudinal growth may occur either due to total degeneration of the cells in the growth cartilage or due to the setting up of a bone bridge between the epi and metaphysis It seems to have been accepted also that minor bone bridges may be fractured by the pressure of growth

but that growth will be definitively arrested if the bridge is so strong that the growth pressure is unable to break it

Experience with Blount stapling has revealed that the growth cartilage may maintain its growth potential through several years although cellular proliferation has been inhibited by external fixation between the epi and metaphysis After stapling growth is generally resumed when the fixation is removed In osseous bridging of the epiphyseal plate the bridge may be expected to re appear after resection However there is a theoretical possibility of inhibiting its re appearance or of preventing re fixation of the bony bridge to the metaphysis while regeneration of the cartilage cells in the growth cartilage is taking place

This was attempted by *Key & Ford* and by *Friedenberg* by packing the defect in the cartilage with bone wax or the like Another possibility is temporary blocking of metaphyseal vascular supply This is obtained by placing a polyethylene membrane between the growth cartilage and the metaphysis or by resecting part of the metaphysis This might weaken the attachment of the bony bridge to the metaphysis and inhibit the healing of spontaneous fractures in the bony bridge

According to *Blout* (1954) most cases of epiphyseal arrest after removal of Blount staples are due to injury to the peripheral part of the epiphyseal plate and of the periosteum It seems reasonable to investigate whether such injury influences the course after epiphyseal trauma This might also elucidate the role of the peripheral versus the central part of the growth cartilage in cartilage cell regeneration

PRESENT INVESTIGATIONS

Object

(1) To devise a standardized epiphyseal trauma which entails permanent retardation of growth but without injuring a larger area of the growth cartilage than necessary

(2) To work out methods for counteracting posttraumatic osseous bridging of the epiphyseal plate and methods for breaking down and inhibiting the recurrence of osseous bridging

Material and Methods of Examination

The experiments were performed on 45 animals 5 of which died before the results could be finally assessed Out of the remaining ani

mals 6 were puppies and 34 albino rabbit young As the experiments extended over several years it was not possible to use animals of the same strain or in the same age or weight groups In comparing the effect of various procedures therefore, the results were as far as possible assessed on the basis of the growth of the two hind legs of the same animal

The 40 animals were subjected to a total of 100 operations 74 primary and 26 secondary procedures all upon the proximal end of the tibia

Metal markers were placed in the proximal tibial metaphysis on both sides

X ray control was performed at 1 week intervals during the first 4-6 weeks after the operation thereafter at 2-4 week intervals

Apart from the X ray examinations during the operations all the X ray examinations were done on animals in the waking state The rabbits were held sitting on the X ray plate and the dogs were X rayed standing from behind since it proved impossible to fix alert animals on an extension table Although completely uniform projections could not be obtained the course of the growth curves shows that the inaccuracy of the measurements must have been within ± 2 mm in the great majority of cases Post mortem X ray measurements on dissected bones can carry but minimal measuring errors

After the experimental period was over the tibiae were dissected and the proximal tibial end sawn in the frontal plane into slices of approx 2 mm The slice which showed the most pronounced changes of the growth cartilage when viewed in a hand lens was fixed in 10 per cent formalin for 7 hours decalcified for 8-10 days in equal parts of formic acid 40 per cent and sodium formiate 7 per cent The decalcified preparations was cut into sections of 7 μ and stained with haematoxylin as well as by the van Gieson Hansen method

The cutting of the preparations up to 2 × 3 cm large and also after the decalcification of somewhat varying consistency caused a good deal of trouble About one-quarter of the preparations got torn so that they were partially inapplicable for histological appraisal

In the histological assessment stress was laid particularly upon demonstrating the presence of vascular or bony bridges (Figure 3) and upon assessing the activity of the cartilage Normal differentiation of the cartilage cells co existing with a normal arrangement of the metaphyseal vessels and of the primary bony trabeculae were used as criteria of normal function (Figure 1)



Figure 1 *Normal active growth cartilage from a rabbit From the top downwards Basement plate growth cartilage and metaphysis (haematoxylin eosin × 10)*

A normal orientation is taken to mean that the columns of cartilage cells are arranged parallel to each other and to the long axis of the bone In normal growth cartilage there is normal orientation and activity but in a number of the preparations there was distinct activity in spite of a more or less marked disorganization

Intermediate metaphyseal formation is taken to mean the phenomenon described by *Brashear* viz ossification arising from perichondrial vessels in an intermediate layer of the growth cartilage

Continuity of the growth cartilage is taken to mean no vascular or bony bridging This is not tantamount to the cartilage being organized or active

Whenever an animal was first subjected to bilateral trauma followed by attempt at repair on one side the choice of the side of the second operation was always done by a person who was not aware of the object of the study or of the course of the primary operation

The effect of the procedures was assessed on the basis of X rays increment curves and histological investigation of the growth zones

METHODS OF OPERATION

(cf Table 1)

(a) *Drilling*

Simple piercing of the growth cartilage was done with a 3 mm drill in rabbits and with a 4–5 mm drill in dogs from the medial metaphysis through the growth

Table 1 Surgical procedures and effect on growth

Group	Operation	Schematic presentation of operation	Number of legs operated upon: Isolated operations	Combined with or prior to other procedures	Total	Effect on Growth after isolated operations: None or slight	Marked
1	Drilling		8	8	16	8	0
2	Epiphyseolysis + Curettement		12	11	23	10(+1)	1
3	Epiphyseolysis + Drilling		2	2	4	0	2
4	Epiphyseolysis + Drilling + Curettement		17	11	26	4 (23 5%)	13 (76 5%)
5	Drilling followed by epiphyseolysis + resection of bone bridge		8	–	8	5	3
6	Epiphyseolysis + Curettement + resection of periosteum		8	–	8	6(+1)	1
7	Group 3 or 4 followed by reception of metaphysis		13	–	11	5 (61 5%)	8 (38 5%)

cartilage and into the epiphysis In other cases the piercing was done through the growth cartilage into the epiphysis after epiphyseolysis had been carried out.

(b) *Epiphyseolysis*

This operation was performed through a longitudinal incision over the medial metaphysis The epiphyseal line was easily located in all the primary operations while in the secondary procedures this was often difficult. The periosteum was incised transversely just below the epiphyseal line in one third to one half of its periphery By firmly grasping the epiphysis and metaphysis and simultaneously carrying the tibia into external rotation and valgus epiphyseolysis could in variably be created The separation occurred through the degenerative layer of the growth cartilage or through the primary calcification zone In a few cases fracture occurred in the lateral corner of the metaphysis which accompanied the epiphyseal fragment.

The separation required somewhat varied force but it was always easy in the primary operation on rabbits somewhat more difficult in the secondary operation on rabbits and primary operations on the puppies and often extremely difficult in the secondary operations on the puppies

The metaphyseal width in the rabbits was about 15 mm and in the dogs about 35 mm—which explains the difference in the firmness of the metaphyseal attach ment

After reduction the epiphysis was fixed by suturing the soft tissues The max imum lateral displacement after reduction was 2 mm. No dressing was applied, and there was no instance of secondary dislocation

(c) *Curetting of the Growth Cartilage*

After epiphyseolysis has been performed and the tibia had been carried into valgus the growth cartilage was curetted as far as the basement plate in a circular area beneath the medial condyle, comprising about 10 per cent of the cartilaginous area The limit between cartilage and basement plate was always extremely distinct

(d) *Resection of Transepiphyseal Bone Bridges*

In this procedure epiphyseolysis as described above was first done In all cases the preformed bone bridge became separated from the metaphysis and projected like a peg from the under aspect of the growth cartilage This peg was removed on a level with the basement plate while sparing the surrounding cartilage as far as at all possible

(e) *Resection of Periosteum and Perichondrium Medially on the Proximal Tibia*

This was done by removing the medial third of the periosteum and perichondrium with a sharp knife in the region of the epiphyseal line and on the proximal 8 mm of the tibia. The resection was carried so deep that the epiphyseal line stood out distinctly against the surrounding spongy bone

(f) *Metaphyseal Resection*

This procedure was performed in one case by chiselling off a 4 mm high area of the metaphysis reaching to th under aspect of the growth cartilage I owever as

this procedure was felt to be highly traumatizing it was done in the subsequent cases by sawing two tracks in the metaphysis the upper one as close as possible to the growth cartilage in practice 2-3 mm below it and the lower track 4-5 mm inferior to the first one The bone was sawn through one third to one half of its width with an electric circular saw and the intermediate piece of bone was removed. In all cases a wide aperture to the medullary cavity was made.

RESULTS

(cf Table 1)

(1) *Drilling*

The effect of this procedure could be assessed on 8 tibiae Growth continued in all cases entirely or almost unchanged

Histological study at the end of 62-97 days revealed in 2 cases a cord of cartilage in the epiphysis presumably generating from cartilage cells which had become displaced into the drill hole (Figure 2) In the other cases the histological appearances were normal



Figure 2 Regeneration of cartilage in drill hole (arrow) A rabbit 76 days after drilling through the growth cartilage Inferiorly on the left normal growth cartilage (haematoxylin eosin × 10)

As already mentioned growth continued unchanged or with only a transient retardation in all the control legs

On the re operated side growth continued unchanged in one case In 4 cases a transient arrest of growth resulted in a shortening of 2–6 mm as compared with the control leg In 3 cases permanent arrest of growth occurred in the entire growth cartilage or parts thereof Histological examination revealed on the re operated side entirely normal appearances in 2 out of 5 rabbits Another two had only atrophic *remnants of the growth cartilage peripherally around a wide central* bone bridge In one case there was a narrow central bone bridge surrounded by normal cartilage, cartilaginous regeneration in the drill hole and a small intermediary ossification medially in the growth cartilage

(6) *Epiphyseolysis Combined with Curetting of the Growth Cartilage and with Resection of the Periosteum and Perichondrium Medially on the Tibia*

This was done on 8 rabbits one of which died at the end of 11 days while 2 were followed for 25–31 days and the remainder for 77–79 days

In 6 no or only transient retardation of growth occurred while one exhibited severe varus deformity and gradually total arrest of growth

Comparison with the control leg which had been subjected only to epiphyseolysis and curetting showed identical appearances (transient retardation of growth) in 4 In 2 the inhibition affected the side where periosteal resection had been done the shortening being 2–3 mm compared with the control leg In the case showing total arrest of growth the control leg went on growing normally The remaining rabbits were not followed for a sufficient length of time to assess the effect

Histology showed in the rabbit with total arrest of growth a narrow disorganized growth cartilage *with multiple bone bridges* Three had a narrow (1 mm) central bone bridge surrounded by normal cartilage (Figure 3) In 2 the cartilage was continuous and only slightly disorganized at the site of the curetted area In the rabbit followed for only 11 days the epiphyseal cartilage was very tall medially but in other respects this preparation was unassessable

In 4 cases (including the one of 11 days duration) the periosteum as well as Ranvier s perichondrial groove had regenerated In 2 of these cases a major accumulation of cartilage cells was found in ample



Figure 3 Bone bridge between epiphysis and metaphysis Laterally to the bone bridge slightly disorganized but active growth cartilage A dog 118 days after epiphyseolysis curetting and drilling followed by metaphyseal resection (haematoxylin eosin × 10)

ground substance deep into the perichondrial groove In the remaining 3 cases the quality of the preparations did not permit a definite assessment of the structures on the medial side

(7) *Metaphyseal Resection*

This procedure was carried out on 13 animals 3 dogs and 10 rabbits The primary injury inflicted on 2 of the animals had been epiphyseolysis and drilling while the remainder had been subjected to epiphyseolysis drilling and curetting All the primary operations were bilateral and all the secondary ones unilateral done 21–29 days after the primary procedures

Two of the rabbits were so old at the time of the procedure that their growth period had presumably been completed by the time the control period was over Therefore the effect in these cases could be assessed only on the basis of X ray findings and growth curves (In one of the cases the appearances were identical on both side while in the other case growth was more normal on the control leg)

In 4 cases growth conditions were clearly less abnormal on the re operated side

In 1 case growth curves and X ray findings were identical but the *histological examination showed the growth cartilage to be disorganized* and inactive on the control side while on the side of the metaphyseal resection it was continuous and active apart from a slight central irregularity

In 2 cases the findings were distinctly more abnormal on the side of the metaphyseal resection than on the control side

In 6 cases the findings on the two legs did not differ definitely 5 cases showing total arrest of growth and 1 case transient growth retardation on both sides

The results are presented in Table 2

Table 2 Effect of metaphyseal resection

Improvement	Exacerbation	No change
5	2	6

The demonstrated effect is not statistically significant

In 2 of the 4 cases where the appearance were distinctly better on the treated side, X ray findings and growth curve prior to the secondary *procedure seemed to indicate that the initial trauma had been more* severe on the untreated side In one of the 2 cases with exacerbation on the treated side the same criteria indicated that the initial trauma had been more severe on this side

DISCUSSION

After piercing the growth cartilage with a drill about one fifth of the diameter of the growth cartilage bone bridge formation in the drill *hole was demonstrable in all 8 cases which were subjected to epi* physeolysis 2–3 weeks later However growth continued unchanged or only transiently inhibited on all legs which had not been subjected to re operation and which have presumably at the same time also been affected with bridging This must indicate that normally the pressure of growth will be able to break a minor bone bridge or rather tear it from the metaphysis

The predominantly normal histological findings at the end of the experiment show that such minor bone bridges may disappear almost *without leaving a trace*

Curetting of approx 10 per cent of the growth cartilage caused permanent arrest of growth in only one of the 11 studied cases At

histological examination the curetted area had in the great majority of cases filled with normally oriented and active growth cartilage showing that the cartilage cells must possess a considerable ability for regeneration

In these animals the basement plate was intact while in those in whom curetting was supplemented by drilling through the basement plate 13 out of 17 (76 5 per cent) showed permanent retardation of growth—even when the drill had been of the same bore as that which had not caused major changes in growth when the drilling had been the only inflicted injury

Epiphyseolysis and drilling without curetting were performed on only 2 animals but caused growth arrest in both

It may be concluded therefore that even fairly extensive loss of substance in the growth cartilage may be restored provided that the basement plate is intact Minor injuries to the cartilage and basement plate rarely result in arrested growth if the cartilage is otherwise intact On the other hand damage to the cartilage in the form of loss of substance and compression injuries associated with epiphyseolysis and combined with damage to the basement plate involve a high frequency of growth arrest

This observation indicates that the conventional technique of the Phemister epiphyseodesis which aims at arresting growth definitively should be supplemented by drilling of the basement plate

The basement plate is a continuous compact plate of bone with only a few and small holes admitting the vessels to the germ cell layer of the growth cartilage According to *Trueta & Amato* (1960) the formation of a bone bridge is invariably preceded by a vascular bridge It is conceivable that a massive vascular bridge between the epi and metaphyseal vascular system cannot be developed through the small apertures in the intact basement plate On the other hand an effusion can soon accumulate in the fracture like slit which occurs when cartilage as well as basement plate are injured This effusion may become organized become traversed by vessels and undergo ossification into a solid bone bridge before regeneration of cartilage cells has occurred In order to study this development in more detail it is necessary to supplement the technique by studying the effect of injections into the vessels at suitable intervals after the operations However this was beyond the scope of the present study

To prevent contact between growth cartilage and metaphysis a thin membrane of polyester was inserted into the epiphyseolysis slit left by

cartilage injury in a number of animals Owing to the small size of the anatomical structures, however it proved difficult to place this membrane in the correct position Infection occurred in several cases and invariably there was a considerable tissue reaction around the membrane which in several cases became displaced Accordingly this technique had to be abandoned

All minor bony bridgings after drilling procedures were followed by spontaneous normalization of the growth On the other hand resection of small bone bridges often resulted in severe inhibition of growth The explanation is presumably that the growth cartilage had been exposed to a severe compression injury in the course of the relatively difficult epiphyseolysis at the secondary procedure

Epiphyseolysis and curetting of the growth cartilage as an isolated procedure did not leave permanent arrest of growth Resection of the perichondrium and periosteum on a level with the cartilage injury and in connection with this injury did not change the course This indicates that an intact periphery of the growth cartilage does not play a decisive role in regeneration after loss of substance in the latter The regeneration of a structure which corresponds morphologically to Ranvier s perichondrial groove observed in several cases confirms *Lacroix s* (1951) findings of regeneration of this structure However the course of growth does not indicate that it is of specific importance to the function of the growth cartilage as claimed by *Lacroix*

The results of metaphyseal resection might indicate that in some cases this procedure is able to inhibit the development of a solid bone bridge However the results are not significant To study in more detail the effect of this procedure and perhaps elaborate the technique this operation must be performed on a larger series of larger animals whose anatomical appearances correspond more to those in children Furthermore the experiments must be supplemented by a series in which the vessels are injected and prepared at suitable intervals after the operation On the basis of experience made so far it is not justified to employ metaphyseal resection clinically in the treatment of post traumatic growth arrest

SUMMARY

34 rabbit young and 6 puppies were subjected to a number of mechanical injuries to the growth cartilage followed by various procedures done with a view to affecting growth after the traumas

Drilling through the growth cartilage with small bore drills did not ever result in permanent arrest of growth—and curetting of approx 10 per cent of the growth cartilage seldom

On the other hand epiphyseolysis as well as epiphyseolysis plus curetting of the cartilage caused permanent bony bridging in 76 5 per cent when the procedure was combined with drilling through the basement plate

When combined with epiphyseolysis and curetting excision of the periosteum and perichondrium on a level with the injury did not definitely alter the course

Resection of minor bone bridges left by drilling aggravated the prognosis

Resection of the metaphysis below a major injury to the growth cartilage resulted in somewhat but not significantly improved growth as compared with the control leg which had been subjected to the same injury but without subsequent metaphyseal resection Pending further studies the clinical use of metaphyseal resection is not justified

REFERENCES

Aitken A P (1936) The End Results of the Fractured Distal Tibial Epiphysis *J Bone Jt Surg* 18 685

Blount W P (1954) Discuss *J Bone Jt Surg* 36 A 1069

Brashear H R jr (1959) Epiphyseal Fractures A Microscopic Study of the Healing Process in Rats *J Bone Jt Surg* 41 A 1055

Campbell C J Grisolia A & Zanconato G (1959) The Effects Produced in the Cartilaginous Epiphyseal Plate of Immature Dogs by Experimental Surgical Traumata *J Bone Jt Surg* 41 A 1221

Dale G C & Harris W R (1958) Prognosis of Epiphyseal Separation An Experimental Study *J Bone Jt Surg* 40 B 116

Ford L T & Key J A (1956) A Study of Experimental Trauma to the Distal Femoral Epiphysis in Rabbits I *J Bone Jt Surg* 38 A 84

Friedenberg Z B (19 7) Reaction of the Epiphysis to Partial Surgical Resection *J Bone Jt Surg* 39 A 332

Goff C W (1960) Surgical Treatment of Unequal Extremities Springfield Illinois

Green W T & Anderson M (1957) Epiphyseal Arrest for the Correction of Discrepancies in Length of the Lower Extremities *J Bone Jt Surg* 39 A 853

Heikel H V A (1961) Experimental Epiphyseal Transplantation *Acta orthop scand* 30 1

Key J A & Ford L T (1958) A Study of Experimental Trauma to the Distal Femoral Epiphysis in Rabbits II *J Bone Jt Surg* 40 A 887

Lacroix P (1951) The Organization of Bone J & A Churchill London

Langenskiold A & Edgren W (1950) The Growth Mechanism of the Epiphyseal Cartilage in the Light of Experimental Observations *Acta orthop scand* 19 19

Nordentoft E. L. (1964) Den operative Epifyseodese With a Summary in English Munksgaard København
Rigal W M (1961) Tritiated Thymidine in Studies of Chondrogenesis *J Bone Jt Surg* 43 B 180
Ring P A (1955) Transplantation of Epiphyseal Cartilage *J Bone Jt Surg* 37 B 642
Troupp H (1961) Nervous and Vascular Influence on Longitudinal Growth of Bone *Acta orthop scand* Suppl 51

Acta orthop Scandinav 40 193–197 1969

Department of Physiology University of Malaya Kuala Lumpur Malaysia

APPOSITIONAL GROWTH RATE IN RAT BONES USING THE TETRACYCLINE LABELLING METHOD

By

A Raman

Received 4 x 67

In 1957 it was first observed by *Milch* and others that the tetracycline antibiotics became localised in areas of new bone formation and since then a large number of reports have been published on the tetracycline labelling technique for the study of bone growth in human material as well as animals such as dogs and cats (*Frost et al* 1960 *Lee et al* 1965 *Manson & Waters* 1965) However quantitative studies on bone growth in rats have been few though the rat is a commonly used laboratory animal This may be due to difficulties in making serial sections of undecalcified rat bones it being known that the osteoblastic activity is irregular in rat bones and a true illustration of the amount of osteoblastic activity requires examination of a large number of serial sections A rapid method for producing serial sections of undecalcified rat bones was recently described (*Raman* 1966b) and this method was used in conjunction with the tetracycline labelling technique for the study of appositional bone growth in rats

MATERIALS AND METHODS

Male Wistar rats of known age were chosen and grouped according to age so that there were seven groups of 10 animals each ranging in age from 4 weeks to 16 weeks. They were fed rat pellets and water On the first day of the experiment the rats were given an intra peritoneal injection of Terramycin (Pfizer) 40 mg/kg body weight in normal saline and the drug was repeated in the same dosage on the eleventh day The animals were killed with chloroform forty eight hours after the second injection and the femurs and tibiae immediately removed and dehydrated in absolut alcohol After embedding in Tensol cement (*Raman* 1966a) serial sections of the diaphyses of the bones were cut by the method previously described The sections were ground to a thickness of approximately 50 μ and mounted in D P X

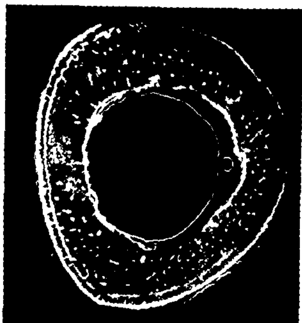


Figure 1 Photomicrograph of a section of tibia showing the two complete rings of tetracycline label (Unstained ground section in ultra-violet light × 120)

and examined in transmitted ultra violet light with a Leitz fluorescent microscope On the average it was possible to obtain 40 sections from the femurs and 30 sections from the tibiae

Although most of the sections showed two complete rings of tetracycline labels (Figure 1) there were a few sections especially from the animals in the younger age group in which the rings were incomplete Whether the rings were complete or not each section was examined and the distance between the rings of tetracycline labels on the periosteal side were measured to the nearest micron using a Leitz screw micrometer eyepiece Eight random readings were taken for each section at different points and averaged and the process was repeated for all the sections from each bone and the mean appositional growth rate on the periosteal aspect was calculated

RESULTS

The results are given in Tables 1 and 2

DISCUSSION

The rate of appositional growth was greatest in the younger animals and decreased with increasing age of the animals (Figure 2) The femur grew more rapidly than the tibia in the younger animal and as the animal got older the rate of growth in the two bones tended to become uniform Comparison of the percentage increase in body weight with the growth rates in the bones showed a similar pattern These results

Table 1 Appositional growth rate in femur

Group	Age	Mean distance between tetracycline labels in μ	App growth rate/day in μ	S.E. ±
I	4 weeks	105	10.5	± 0.17
II	6 weeks	76	7.6	± 0.11
III	8 weeks	60	6.0	± 0.13
IV	10 weeks	46	4.6	± 0.10
V	12 weeks	36	3.6	± 0.13
VI	14 weeks	27	2.7	± 0.07
VII	16 weeks	24	2.4	± 0.10

Average of 10 animals

Table 2 Appositional growth rate of tibia

Group	Age	Mean distance between tetracycline labels in μ	App growth rate/day in μ	S.E. ±
I	4 weeks	83	8.3	± 0.10
II	6 weeks	63	6.3	± 0.10
III	8 weeks	48	4.8	± 0.08
IV	10 weeks	40	4.0	± 0.11
V	12 weeks	29	2.9	± 0.09
VI	14 weeks	22	2.2	± 0.06
VII	16 weeks	19	1.9	± 0.06

Average of 10 animals

are in agreement with those of *Tapp* (1966) who studied the rate of increase in the cross sectional area of tibiae of rats with age

Whereas most of the sections from the older animals showed two clear rings of tetracycline labels in sections of bones from animals in the younger groups the rings were incomplete This was due to the extensive remodelling that takes place in younger bones *Frost et al* (1961) do not consider it justifiable to include sections which lack two complete rings because they feel that bone forming in these areas does so under the protection of different control and triggering mechanisms than that formed in the making of concentric bands On the other hand if sections consisting of two complete rings are the only ones measured it will not be truly representative of the osteoblastic activity of the bone as a whole because the osteoblastic activity in rat bones varies from one part to another of the same bone It is therefore felt that if a

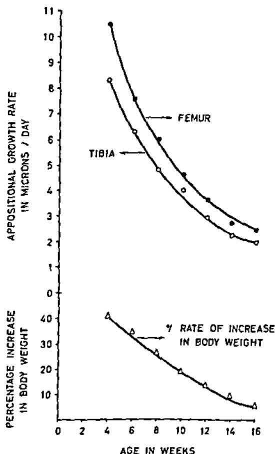


Figure 2 The variation in the appositional growth rates of the femur and tibia and the percentage increase in body weight plotted against the age of the animals

large number of serial sections from each bone are examined and measured a more accurate picture of the growth rate could be obtained

The method is useful for measuring the periosteal appositional growth rates in the diaphysis and it is possible to measure endosteal growth rate in a similar way Further the method could be used to study rates of bone growth under various conditions such as the influence of hormones and drugs and these could be compared with growth under physiological conditions

SUMMARY

The periosteal appositional growth rates in the femurs and tibiae of rats of different ages were measured using the tetracycline labelling technique It was seen that the growth rates declined as the animals became older and it is suggested how a study like this could give information on bone growth rates under different experimental conditions

RESUME

Les taux de la croissance appositionelle proximale du femur et du tibia chez des rats de differents ages ont ete mesures au moyen de la technique de la coloration a la tetracycline On a constate que les taux de crossance tombent au fur et à mesure que les animaux deviennent plus agés On suggere qu une etude de ce genre est susceptible de donner des informations sur les taux de croissance des os dans differentes conditions experimentales

ZUSAMMENFASSUNG

Die periostale appositionelle Wachstumgeschwindigkeit an Femuren und Tibiae von Ratten verschiedenen Alters wurde mittels der Tetracykline Markierungstechnik gemessen Man sah dass die Wachstums geschwindigkeit mit zunehmenden Alter der Tiere abnahm und man meint dass eine gleichartige Studie Aufschluss über Knochenwachstumsgeschwindigkeit unter verschiedenen experimentellen Bedingungen geben konnte

ACKNOWLEDGEMENT

Thanks are due to Professor G H *Bell* Department of Physiology Queen s College Dundee Scotland for introducing me to this study and to the Department of Medical Illustrations University of Malava Kuala Lumpur for preparation of the figures

REFERENCES

Frost H M Villanueva A R. & Roth H. (1960) Measurement of bone formation in a 57 year old man by means of tetracyclines *Henry Ford Hosp M Bull* 8 238–254

Frost H M., Roth H., Villanueva A R. & Stanisavljevic M. D (1961) Experimental multiband tetracycline measurement of lamellar osteoblastic activity *Henry Ford Hosp M Bull* 9 312–329

Lee W R. Marshall J H & Sissons H A (1965) Calcium accretion and bone formation in dogs. *J Bone Jt Surg* 47 B 157–180

Manson J D & Waters N E. (1965) Observations on the rate of maturation of the cat osteon *J Anat., Lond* 99 539–549

Milch R. A Rall, D P & Tobie J E. (1958) Fluorescence of tetracycline antibiotics in bone *J Bone Jt Surg* 40 A 897–910

Raman A (1966a) A rapid method of embedding bones and teeth. *Far East Med J* 2 197–198

Raman A (1966b) A rapid method for producing serial undecalcified sections of bones *Acta orthop scand* 37 330–341

Tapp E. (1966) Tetracycline labelling methods of measuring the growth of bones in the rat. *J Bone Jt Surg* 48 B 517–525

Acta orthop Scandinav 40 198-204 1969

From the Orthopaedic Hospital Aarhus Denmark
(Head Professor Eivind Thomasen M D)

OSTEOID OSTEOMA

By

JENS O POULSEN

Received 9 1 68

Osteoid osteoma is a not entirely uncommon benign skeletal lesion Nevertheless it is striking that the diagnosis often gives rise to difficulties *Bergstrand* (1930) reported two cases which according to the description have no doubt been osteoid osteomas *Jaffe* (1935) was the first to describe the disease as a pathological and clinical entity In his opinion the lesion represented a benign tumour This theory has been supported by practically all subsequent authors although a few have interpreted it as chronic inflammation (*Brown & Ghormley* 1943) According to *Dahlin* (1957) 10 per cent of all benign tumours of bone are osteoid osteomas The disease is more common in males than in females

CLINICAL AND X RAY FINDINGS

Constant aching pain of increasing intensity is characteristic The pain is worst at rest and may disappear entirely when the patient is moving about Frequently salicylates afford relief As a rule the pain is localized but may be radiating and this causes differential diagnostic difficulties

Clinical examination reveals localized tenderness and swelling may be present also When affecting a limb the disease may give rise to muscular atrophy and when affecting the spine to postural abnormalities (*Rushton et al* 1955 *Maclellan et al* 1967) Effusion in an adjacent joint has been reported (*Sherman* 1947) and neurological signs in the form of sensibility disturbances and lacking tendon reflexes may occur (*Rushton et al* 1955) Deformities of a limb may occur in children because of involvement of the epiphysis (*Ponseti* 1947 *Flaherty et al* 1956) Because of the disproportion between the severe pain and the

usually slight objective changes the patient may risk being labelled as a neurotic

The most valuable diagnostic aid is X ray examination although the findings may be negative at the time of appearance of the first symptoms *Sherman* (1947) therefore has stressed the importance of repeated X ray examinations which should always be done in several projections The typical X ray film presents a small translucency surrounded by sclerosed bone This is the so called nidus which seldom exceeds 1 cm in diameter In some cases the sclerosis is so marked that the nidus cannot be distinguished In that event tomography is of great value At times the entire painful limb and in some cases also the spine has to be X rayed to arrive at the diagnosis *Lindbom et al* (1960) have called attention to angiography as a method for visualizing the nidus because of the high vascularization of the lesion

PATHOLOGY

To render a definite histological diagnosis possible the nidus has to be removed with a block of the surrounding sclerosed bone The nidus is round or oval of a greyish or brownish colour In consistency it may range from soft granulation like to firm brittle tissue The characteristic microscopic finding is a highly vascularized connective tissue lined with osteoblasts and surrounded by well defined sclerosis of the bone consisting of a network of anastomosing osteoid trabeculae Although this appearance is typical *Brown & Ghormley* (1943) have published 14 operated cases 10 of which aroused a suspicion of chronic inflammation on microscopic examination These authors deduced that osteoid osteoma is a variant of inflammation *Golding* (1954) explained the violent pain as a consequence of increased tension in the nidus due to the high vascularization

The prognosis is favourable There have been no reports of malignant degeneration Spontaneous regression is said to occur (*Moberg* 1951 *Vickers et al* 1959) Operative treatment is curative and affords immediate relief of pain X radiation has no effect upon the lesion

PRESENT MATERIAL

In the Orthopaedic Hospital Aarhus 13 cases of osteoid osteoma have been treated by operation All were confirmed microscopically Moreover there has been a case in which the diagnosis could not be con

Acta orthop Scandinav 40 198-204 1969

From the Orthopaedic Hospital Aarhus Denmark
(Head Professor Eivind Thomasen, M D)

OSTEOID OSTEOMA

By

JENS O POULSEN

Received 9 1 68

Osteoid osteoma is a not entirely uncommon benign skeletal lesion Nevertheless it is striking that the diagnosis often gives rise to difficulties *Bergstrand* (1930) reported two cases which according to the description have no doubt been osteoid osteomas *Jaffe* (1935) was the first to describe the disease as a pathological and clinical entity In his opinion the lesion represented a benign tumour This theory has been supported by practically all subsequent authors although a few have interpreted it as chronic inflammation (*Brown & Ghormley* 1943) According to *Dahlin* (1957) 10 per cent of all benign tumours of bone are osteoid osteomas The disease is more common in males than in females

CLINICAL AND X RAY FINDINGS

Constant aching pain of increasing intensity is characteristic The pain is worst at rest and may disappear entirely when the patient is moving about Frequently salicylates afford relief As a rule, the pain is localized but may be radiating and this causes differential diagnostic difficulties

Clinical examination reveals localized tenderness and swelling may be present also When affecting a limb the disease may give rise to muscular atrophy and when affecting the spine to postural abnormalities (*Rushton et al* 1955 *Maclellan et al* 1967) Effusion in an adjacent joint has been reported (*Sherman* 1947) and neurological signs in the form of sensibility disturbances and lacking tendon reflexes may occur (*Rushton et al* 1955) Deformities of a limb may occur in children because of involvement of the epiphysis (*Ponseti* 1947 *Flaherty et al* 1956) Because of the disproportion between the severe pain and the

usually slight objective changes the patient may risk being labelled as a neurotic

The most valuable diagnostic aid is X ray examination although the findings may be negative at the time of appearance of the first symp toms *Sherman* (1947) therefore has stressed the importance of re peated X ray examinations which should always be done in several projections The typical X ray film presents a small translucency surrounded by sclerosed bone This is the so-called nidus which sel dom exceeds 1 cm in diameter In some cases the sclerosis is so marked that the nidus cannot be distinguished In that event tomography is of great value At times the entire painful limb and in some cases also the spine has to be X rayed to arrive at the diagnosis *Lindbom et al* (1960) have called attention to angiography as a method for visualizing the nidus because of the high vascularization of the lesion

PATHOLOGY

To render a definite histological diagnosis possible the nidus has to be removed with a block of the surrounding sclerosed bone The nidus is round or oval of a greyish or brownish colour In consistency it may range from soft granulation like to firm brittle tissue The characte ristic microscopic finding is a highly vascularized connective tissue lined with osteoblasts and surrounded by well-defined sclerosis of the bone consisting of a network of anastomosing osteoid trabeculae Although this appearance is typical *Brown & Ghormley* (1943) have published 14 operated cases 10 of which aroused a suspicion of chronic inflammation on microscopic examination These authors deduced that osteoid osteoma is a variant of inflammation *Golding* (1954) explained the violent pain as a consequence of increased tension in the nidus due to the high vascularization

The prognosis is favourable There have been no reports of malig nant degeneration Spontaneous regression is said to occur (*Moberg* 1951 *Vickers et al* 1959) Operative treatment is curative and affords immediate relief of pain X radiation has no effect upon the lesion

PRESENT MATERIAL

In the Orthopaedic Hospital Aarhus 13 cases of osteoid osteoma have been treated by operation All were confirmed microscopically More over there has been a case in which the diagnosis could not be con

firmed microscopically because of too small a specimen but the clinical and radiological findings were typical of osteoid osteoma The sites of the tumours were as follows Femur (6) tibia (2) spine (1) talus (2) radius (1) cuneiform bone (1) and a phalanx of a finger (1) Of the 14 patients 4 were females and 10 males The youngest patient was 5 years and the oldest 60 years of age The oldest patient had a sclerosed osteoid osteoma The two youngest patients were 5 and 6 years but otherwise the age ranged from 15 to 38 The predominant symptom was pain All cases showed positive X ray findings although in 2 cases affecting the neck of the talus and the spine tomography was required to visualize the lesions At operation the nidus was demonstrated macroscopically in 9 cases In 2 cases the lesion looked like inflammation and in 1 case like a haematoma at operation, but in all cases the microscopic findings were typical

*The duration of symptoms from the first examination in the Ortho*paedic Out patient Department until operation was performed ranged from 2 months to 1 year 12 patients were relieved of pain immediately after the operation One patient developed a recurrence but was relieved of pain by re operation In the oldest patient it is difficult to assess the condition The lesion affected the radius and the pain in this bone yielded but the patient also has osteoarthritis of the elbow joint which is still causing pain

Three characteristic case histories will be reported below

(1) A 27 year old joiner (Case No 147412) was referred for pain in the left knee of 1 year s duration The pain present during work as well as at rest

Objective findings 2 cm atrophy of the left thigh No other abnormalities X rays of both knee joints in 2 views + special view of the patella AP view of both hips lower leg and left femur failed to reveal any abnormalities Tomography of the lower end of the left femur gave a suspicion in the AP view of a central translucency distally in the femur However this translucency could not be demonstrated on the lateral tomograms The patient was kept under observation and at a new follow up visit a lateral X ray film showed a 4 cm long cortical thickening posteriorly on the femur with a distinct nidus 25 cm above the joint line of the knee (Figure 1)

Operation was performed chiselling off the nidus in a block and microscopic examination revealed osteoid osteoma Free of pain immediately after the operation

(2) A boy aged 5 years (Case No 130646) Six weeks before he was seen in the Out patient Department he had complained of pain in the back and had ever since winced at the slightest touch of the loin

Objective findings Tenderness on a level with the spinous process of L 2 and slight lumbar scoliosis X rays showed a small translucency in the lamina of L 2. This translucency was also observed on pyelography which showed no other



Figure 1 X rays of distal end of right femur in 2 projections The lateral shows cortical thickening with a nidus

Figure 2 Tomography of the spine showing in the arch on the right a translucency surrounded by sclerosed bony tissue





Figure 3 Tomography of the right talus showing an area of irregular sclerosis superiorly in the neck of the talus

abnormalities After the examination had been supplemented by tomography there was no longer any doubt that this lesion was a nidus (Figure 2)

Operation showed thickening of the right arch of L 2 Chiselling disclosed a greyish red tumour somewhate larger than a pea Microscopic examination Osteoid osteoma The patient has been fit ever since

(3) A mechanic s apprentice aged 19 (Case No 118327) Referred to the Out patient Department because of pain in the right ankle joint most severe at rest. No complaints when walking Acetylsalicylic acid alleviated the pain The examination showed no abnormalities

11 months later he was seen again because of pain of a radicular type in the entire right leg There was 2 cm atrophy of the right lower leg and 1 cm atrophy of the thigh The patient was admitted and X ray examination of the right foot disclosed a lesion on the anterior aspect of the neck of the talus (Figure 3) Tomography showed an irregular configuration of the bone at this site Operation revealed a raised area at the anterior edge of the talar joint surface from which a round piece of bone could be lifted Beneath there was a pea sized area of dry brittle bony tissue Micr exam Osteoid osteoma The patient has been free of pain since the operation

SUMMARY

Persistent deep aching pain as a rule worst at rest and responding to acetylsalicylic acid should make one think of osteoid osteoma The pain may be radiating Repeated X ray examinations may be needed to disclose the typical nidus surrounded by sclerosed bony tissue The characteristic microscopic appearances are described Operative removal of the lesion gives immediate relief of pain At operation the nidus should be removed together with a block of bony tissue and an opening should be made to the medullary cavity Curettement is not sufficient as it may be followed by recurrence

Fourteen operated cases are reported and 3 characteristic case histories given The disease is most common in the age range 15 to 30 years but may also occur in children the present material includes two children of 5 and 6 years

RESUME

Douleur profonde persistante d une manière génerale plus accentuée au repos et reagissant a l acide acétylsalicylique est un des traits caracteristiques de l ostéome ostéoide La douleur peut rayonner Des examens radiologiques répétés peuvent etre necessaires pour révéler le foyer typique entouré de tissu osseux sclérosé Les aspects microscopiques caracteristiques sont décrits L enlevement opératoire de la lésion apporte immédiatement un soulagement aux douleurs A l opération le

fóyer doit etre extirpe avec un bloc du tissu osseux et il doit etre prati que une ouverture jusqu à la cavité medullaire Un curetage n est pas suffisant il peut etre suivi d une récidive

Quatorze cas operes sont rapportes et il est donne l histoire de 3 cas caracteristiques La maladie se produit surtout dans la periode d âge entre 15 et 30 ans mais peut aussi etre observee chez des enfants les presentes observations comptent deux enfants de 5 et 6 ans

ZUSAMMENFASSUNG

Konstanter tiefsitzender Schmerz der in der Regel am stärksten in der Ruhe ausgesprochen ist und auf Acetylsalicylsaure günstig reagiert sollte an osteoid Osteoma denken lassen Die Schmerzen können aus strahlend sein Wiederholte Rontgenuntersuchungen konnen notwen dig sein um den typischen Nidus der von sklerosiertem Knochenge webe umgeben ist zu entdecken Der charakteristische mikroskopis che Befund wird beschrieben Operative Entfernung der Erkrankung giebt sofortige Befreiung von den Schmerzen Bei der Operation sollte der Nidus zusammen mit einem Block von Knochengewebe entfernt werden und eine Öffnung zur Markhöhle sollte gemacht werden Cu rettement ist nicht genugend da es von Rückfall gefolgt werden kann

Vierzehn operierte Falle werden berichtet und drei charakteristische Krankengeschichten werden gegeben Die Erkrankung findet man zu meist im Alter von 15 bis 30 Jahren kann aber auch bei Kindern vor kommen Das vorliegende Material schliesst zwei Kinder im Alter von 5 bis 6 Jahren ein

REFERENCES

1 Bergstrand H (1930) Uber eine eigenartige wahrscheinlich bisher nicht be schriebene osteoblastische Krankheit in den langen Knochen der Hand und des Fusses *Acta radiol* 11 596-613

2 Brown R C & Ghormley R K (1943) Solitary eccentric (cortical) abscess in bone *Surgery* 14 541-553

3 Dahlin D C (1957) Bone tumors Thomas Springfield

4 Flaherty R A, Pugh D C & Dockerty M B (1956) Osteoid Osteoma *Amer J Roentgenol* 76 1041-1051

5 Golding J S R (1954) The Natural History of Osteoid Osteoma With a Report of Twenty Cases *J Bone Jt Surg* 36 B 218-229

6 Jaffe H L (1958) Tumors and Tumorous Conditions of the Bones and Joint Lea & Febiger Philadelphia

7 Jaffe H L (1935) "Osteoid Osteoma" A Benign Osteoblastic Tumor Composed of Osteoid and Atypical Bone *Arch Surg* 31 709-728

8 Lindbom, A, Lindwall N Soderberg G & Spjut, H (1960) Angiography in Osteoid Osteoma. *Acta radiol* 54 327–333
9 Löfgren I (1953) Osteoid Osteoma *Acta chir scand* 104 383–404
10 Maclellan, D I & Wilson F C. (1967) Osteoid Osteoma of the spine *J Bone Jt Surg* 49 A 111–121
11 Moberg F (1951) The natural course of osteoid osteoma. *J Bone Jt Surg* 33 A 166–170
12 Ponseti I & Barta C. K. (1947) Osteoid Osteoma *J Bone Jt Surg* 29 767–776
13 Rushton J C. Mulder D W & Lipscomb P R. (1955) Neurologic Symptoms with Osteoid Osteoma. *Neurology* 5 794–797
14 Sherman, Mary S (1947) Osteoid osteoma associated with changes in adjacent joints report of two cases *J Bone Jt Surg* 29 483–490
15 Sherman Mary S (1947) Osteoid osteoma review of literature and report of thirty cases *J Bone Jt Surg* 29 918–930
16 Vickers C.W Pugh D C. & Ivins J C. (1959) Osteoid Osteoma A Fifteen Year Follow Up of an untreated Patient. *J Bone Jt Surg* 41 A 357–358

Acta orthop Scandinav 40 205–215 1969

From the Orthopaedic Clinic (Head Professor Sten Friberg)
Karolinska Institutet Stockholm Sweden

DESMOPLASTIC FIBROMA OF BONE

By

ULF NILSONNE & GUSTAF GOTHLIN

Received 24 iii 68

Cyst like changes in roentgenograms of the skeleton are representative of numerous histo pathological states A probable diagnosis is all that can usually be made from x rays The last few years research into bone tumours has permitted a greater differentiation in the assessment of the histo morphological changes with the recognition and clinical confirmation of new entities in the group known as cystic lesions of bone

A *desmoplastic fibroma* was described by *Jaffe* (1958) as an unusual benign tumour that appears on x rays mostly as a cyst like change in the skeleton The diagnostic term is a reference to the great histological similarity of the tumour to the desmoid tumours in the abdominal muscles Thus the desmoplastic fibroma is greyish white with a firm fibrous consistency Microscopically it presents relatively few small fibroblasts with abundant intercellular material rich in collagen fibres There is no osteoid tissue As a rule x rays show a central cyst like trabeculated change in the metaphysis of a long bone Occasionally however the lesion is more peripheral in which case the cortex is thin and sometimes irregular

The differential diagnosis may be difficult to make in respect of well-differentiated fibrosarcoma chondromyxoid fibroma non ossifying fibroma and fibrous dysplasia The last two states can generally be identified on the basis of the x rays but in the first two instances it may be difficult to differ the lesions from desmoplastic fibroma of bone According to Jaffe the histo pathological differential diagnosis can be made on the following criteria a well-differentiated fibro sarcoma is characterized by an increased richness of clearly poly morphic cells with large plump nuclei The chondroid and myxoid type of tissue in a chondromyxoid fibroma is easy to distinguish from the

fibrous tissue in the desmoplastic fibroma. Non ossifying fibromas contain giant cells as well as foam cells whereas desmoplastic fibromas do not. Finally the tissue in fibrous dysplasia has regions with *metaplastic ossification* whereas there is no osteoid tissue in a desmoplastic fibroma.

Jaffe based his account on five cases with an age range of 9–40 years. *Three of the tumours were found in the tibia* the other two in the femur and scapula respectively. A few more cases of desmoplastic fibroma have been published since Jaffe's report with the same age *distribution but a variety of locations. The tumour appears to be* unusual and we have only found 15 cases in the literature to date (cf Table 1).

A study of our cases of fibrous lesions of bone disclosed 9 cases that represent the entity desmoplastic fibroma according to Jaffe's criteria. These cases are presented in some detail below.

Table 1 References to 15 previously published cases of desmoplastic fibroma of bone

Author	Year	No of cases
Jaffe	1958	5
Whitesides & Ackerman	1960	3
Scheer & Kuhlman	1963	1
Cohen & Goldenberg	1965	2
Godinho et al	1967	1
Dahlin	1967	3
	Total	15

OWN MATERIAL

Case 1 I A female 18 years of age at first admission. For 6 months slowly increasing ultimately severe pains above the right ankle. X ray examination showed *an osteolytic process situated somewhat eccentrically in the distal metaphysis and* epiphysis of the right tibia. The cortex was irregular on the medial side (Figure 1A). Osteosarcoma was thought to be the probable diagnosis on this occasion. Amputation was suggested but the patient refused and was remitted to this clinic. At two operations *firm fibrous tissue was scraped out of the lesion. The first exploration* showed that the process had a distinct but soft cortical wall and had not penetrated into the soft tissues. A histo pathological examination showed a tissue poor in cells and with abundant intercellular material rich in collagen fibres no signs of malignancy diagnosis at present follow up desmoplastic fibroma. An X ray check up 4 years after the operations (Figure 1B) showed a somewhat irregular osseous structure with a well delimited outer cortical contour. Both then and subsequently

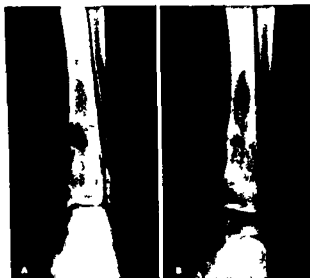


Figure 1 A Desmoplastic fibroma in the distal tibia showing irregular osteolytic destructions B The same case 4 years after curettage now showing a clear cortical margin and a normali ed though irregularly minerali ed osseous structure

the patient was entirely free from discomfort had no pains and normal mobility in the ankle joint Observation time 16 years

Case 2 U R female 30 years of age at first admission Treated with brachy radium inserts for a cancer of colli uteri stage 1 Pains in the right half of the pelvis 8 months later led to an X ray examination which showed an osteolytic destruction close to the iliosacral joint in the right ilium. This was taken to be a metastasis from the uterine cancer and X ray treatment was started The diagnosis was however questioned and an operation was performed at which firm rind like fibrous tissue was scraped from the process in the right ilium The tumour had not invaded the soft tissues A histo pathological examination showed hyalinised fibrous tissue poor in cells and containing fibroblasts with small round nuclei No signs of primary malignant or metastatic cancerous changes Diagnosis at present follow up desmoplastic fibroma The patient s symptoms disappeared after the operative treat ment and she has subsequently remained entirely free from discomfort Nor has any recurrence of the gynecological tumour been noted Observation time 12 years

Case 3 L.P., male 15 years of age at first admission For 6 months pains in the left knee on movement. An X ray examination showed a cystic change almost the size of a walnut located eccentrically in the distal femoral metaphysis where it was expanding at the expense of the cortex At operation intraosseous firm fibrous tissue was removed Microscopically this comprised coarse bundles of hyaline connective tissue poor in cells and without atypical cells Diagnosis at present follow up desmoplastic fibroma. At a clinical examination in 1968 the patient was

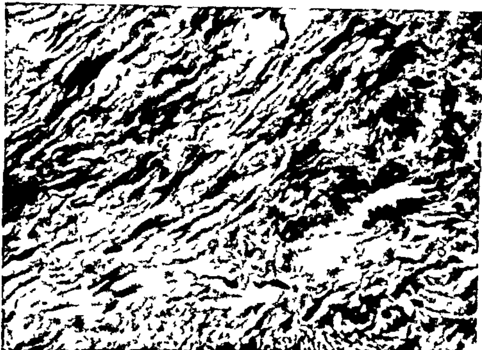


Figure 2 Photomicrograph of desmoplastic fibroma Bundles of dense fibrillary cells with little pleomorphism (× 400)

free from symptoms and roentgenograms showed that the process had healed practically without a trace Observation time 12 years

Case 4 R.A male 16 years of age at first admission For 1 year gradually increasing pain and loss of mobility in the right shoulder An X ray examination revealed osteolytic irregular destruction in the neck of the right scapula At operation 1950 firm rind like material was removed from intraosseous location in collum scapulae A histological examination showed fibrous tissue poor in cells and rich in fibrils (Figure 2) No malignant structures were found The cavities were filled without autologous bone chips (Figure 3 A) The symptoms recurred 10 years later and curettage was undertaken in 1960 and 1961 because X rays suggested that the process might be progressive (Figure 3 B) The microscopic picture was unchanged. Diagnosis at present follow up desmoplastic fibroma At clinical examination in 1968 the patient still had pains in the right shoulder and impaired mobility (abduction 20 forward elevation 30 fixed inward rotation 45) An X ray examination showed small cysts in collum scapulae otherwise normal osseous structure and a moderate arthrosis in the humero scapular joint (Figure 3 C) The patient s discomfort has obliged him to change to a lighter occupation Observation time 18 years

Case 5 B A male 37 years of age at first admission Pains in the right groin for 1 month led to an X ray examination which showed an irregular cystic invasion



Figure 3 *A Curettage and bonegrafting of desmoplastic fibroma in collum scapulae (preoperative X ray films not available) B The same case 10 years later showing multiple cysts in the operated region and irregularities in part of the joint surface and the lateral margin of the scapula C The same case a further 8 years later Only small remnants of the cysts and signs of slight osteoarthritis in the humero scapular joint*

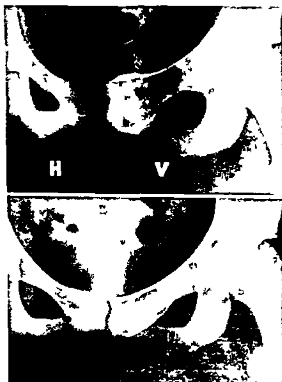


Figure 4 Desmoplastic fibroma in the superior pubic ramus (upper picture) The same case 5 years after curettage and bonegrafting showing an almost normal osseous structure (lower picture)

of the inferior pubic ramus A biopsy showed that the change was entirely intra osseous and contained firm fibrous tissue A histo pathological examination showed a fibromatous tumour poor in cells rich in collagen and without atypical cells The diagnosis was desmoplastic fibroma The tumour was treated with radical re section of the pubic bone from the symphysis to the ischial tuberosity and close to the acetabulum respectively The defect in the floor of the pelvis was covered with plastic netting Fistulas developed postoperatively from the region of the operation and persisted for 3 years The patient was subsequently free from dis comfort with no pains from the pelvic region or the leg No signs of recurrence at X ray check up Observation time 5 years

Case 6 E K female 17 years of age at first admission While skiing the patient suddenly experienced a locking feeling and pains in the left groin without distinct trauma An X ray examination showed a fracture without dislocation through a well defined cyst like change in the superior pubic ramus (Figure 4) An operative exploration 1 month after the onset of symptoms showed that the lesion contained elastic greyish blue material that corresponded histologically to fibromatous tissue poor in cells and without atypical cells In addition however there were traces of chondroid and osteoid tissue formation and occasional giant cells Diagnosis des moplastic fibroma After curettage the cavity was filled with autologous bone chips X ray check ups showed that these united well and in time the structure of the bone became practically normal (Figure 4) The patient s symptoms disappeared entirely Observation time 5 years

Case 7 J H female 71 years of age at first admission For 6 months pains in right shoulder at rest and during movement X ray examination showed several moderately trabeculated cysts in collum scapulae At operation these were extir pated from a pale yellow fibrous tissue Microscopically the lesion consisted of fibromatous tissue poor in cells Diagnosis desmoplastic fibroma Postoperative X ray check ups showed that the structure of the bone gradually normalized The patient become free from discomfort and practically normal mobility returned in the right shoulder joint Observation time 4 years

Case 8 S E female 57 years of age at first admission For 1 year periodical pain in right groin at rest and on walking X ray examination disclosed a cyst like change in the pubic bone just to the right of the symphysis The cortex in the walls of the cavity had become thin and initial signs of calcification were observed in the surrounding soft tissues A surgical exploration showed however that tumour was well delimited within the bone and had not invaded the soft tissues The content of the lesion was extirpated and found to consist of firm shiny fibromatous material Histologically this corresponded to coarse bundles of hyaline fibromatous tissue poor in cells Diagnosis desmoplastic fibroma Postoperatively the patient s symptoms disappeared X ray check ups show that the bone structure is returning to normal though there is sclerosis in the region of the operation Observation time 3 years

Case 9 E S male 39 years of age at first admission Pain at rest and on weight bearing in the left groin for 6 months An X ray examination disclosed a somewhat

Figure 5 Desmoplastic fibroma giving rise to an irregular osteolytic change in the superior ischial ramus (upper picture) The same case 2 years after curettage and bonegrafting showing sclerosis and also some thinner trabeculated areas in the operated region (lower picture)



irregular osteolytic change in the superior ischial ramus (Figure 5) At operation a firm white fibrous mass was found within the bone and was extirpated, the resultant cavity being filled with heterologous bone. A histological examination showed well-differentiated fibrous tissue moderately rich in cells and without cell polymorphism, *Diagnosis* desmoplastic *fibroma* (Figure 6) X ray check ups showed normalization of the bone structure though a thin trabeculated region remained (Figure 5) The patient is subjectively free from discomfort. Observation time 2 years

DISCUSSION

The diagnosis desmoplastic fibroma of bone in these nine cases appears to comply satisfactorily with Jaffe s criteria In all cases the lesion had an *intraosseous* location and the cortical surface was found to be intact at the first exploration The content of the bone lesion consisted of a



Figure 6 Photomicrograph of desmoplastic fibroma. Homogeneous fibrous tissue with interlacing bundles of fibrillary cells (× 150)

firm fibrous tissue generally greyish white in appearance The x rays showed cystic or osteolytic changes with multiple cavities and trabeculation in some cases The extent of the destruction in a few cases suggested the possibility of malignancy The histological examination consistently showed a fibre rich collagen tissue with relatively few cells The fibroblasts were small and not atypical so that well differentiated fibrosarcoma could be ruled out in all cases The long observation times—a range of 5–18 years for six of the cases—also suggest that the processes were not malignant The absence of myxoid and chondroid tissue ruled out a diagnosis of chondromyxoid fibroma In only *one case (Case 3) was there reason to consider a diagnosis of non* ossifying fibroma The x rays showed an eccentric lesion in the femur but the external wall was considerably thinner and bulged more than is usually the case in non ossifying fibroma The histological picture showed the coarse fibrillar bundles that are typical of desmoplastic fibroma in contrast to the looser connective tissue in non ossifying fibroma Osteoid tissue was found in Case 6 which suggested the possibility of a fibrous dysplasia In this case however the biopsy was performed 1 month after a pathological fracture The ossification

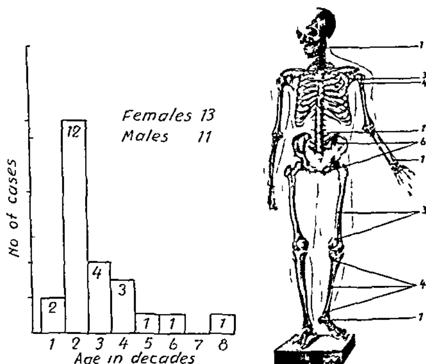


Figure 7 Distribution of 24 desmoplastic fibroma of bone (the 9 cases of the present series being added to the 15 previously published) by sex age and localisation

was therefore taken to be a part of the current callus formation and the predominantly fibrous character of the lesion justified its classification as a desmoplastic fibroma

Desmoplastic fibroma of bone appears to be a rare tumour Dahlin for instance reported only 3 cases out of 3987 bone tumours The 9 cases reported here and the 15 published previously add up to only 24 known cases of desmoplastic fibroma of bone In view of the low incidence it seems justifiable to draw certain general conclusions even though the number of cases is small

As indicated by Figure 7 the tumour may occur at all ages though the second decade predominates More than half of all the cases were diagnosed in the period 10–30 years of age There is no sex difference in the distribution of the tumours The lesion may be located to a long bone as well as to the flat bones It is worth noting that the tumour was in the pelvic bones or the scapula in 7 of the 9 cases reported here

whereas only 2 cases with this location had been reported previously (Jaffe 1 case scapula Whitesides & Ackerman 1 case ilium)

The symptoms are not characteristic, consisting of diffuse moderate pain in the region of the tumour both at rest and on movement and/or weight bearing There may be local pains on palpation but as a rule there is no palpable resistance

X rays of desmoplastic fibroma in long bones show an osteolytic tumour with a central location in the metaphysis The process may be somewhat transparent and is often trabeculated The cortex becomes thinner as the tumour expands and sometimes appears so irregular as to suggest a malignant process Desmoplastic fibromas located in the pelvic bones or the scapula are similar in principle but are often poly cystic with a definitely sclerotic periphery

Desmoplastic fibroma of bone is a benign tumour and can justifiably be treated with local surgery Radical local resection of the lesion into healthy tissue is an acceptable alternative This is often unnecessarily complicated however if the tumour is situated in *e g* the pelvis Re section was employed in only one case in the present series Five of the others were treated with curettage alone and the remaining three with curettage and bone grafting Both methods result in satisfactory bony union although the x rays do not always show a completely normal osseous structure This may indicate that regeneration of the bone occurs spontaneously once the fibrous tissue has been removed We therefore recommend that the cavity resulting from the curettage be filled with bone chips in order to accelerate union

Having verified these nine cases as desmoplastic fibroma of bone it seems likely that the tumour is somewhat more common than was previously supposed After Jaffe s fundamental work it should be possible to be more certain about identifying a fibrous tumour in the skeleton as a desmoplastic fibroma One should be particularly alert as regards cases that have previously been classified as well differen tiated fibrosarcoma particularly if they are reported to have healed The differential diagnosis between these two benign and malignant processes respectively is of the utmost importance for the choice of therapy

SUMMARY

Nine cases of desmoplastic fibroma of bone are reported This is the largest series presented to date and it brings the total number of registered cases to 24 The diagnoses were made according to the cri

teria developed by Jaffe The cases are presented with special reference to the roentgenologic and histological findings and to the principles of treatment

ACKNOWLEDGEMENT

Professor *Lars Santesson* M D Head of the Department of Radio pathology Karolinska Sjukhuset, Stockholm has given us kind and valuable help in the assessment of the histologic specimens for which we are most grateful

REFERENCES

1 Cohen Ph & Goldenberg R R (1965) Desmoplastic fibroma of bone *J Bone Jt Surg* 47 A 1620
2 Dahlin D C (1967) *Bone Tumours* Charles C Thomas Publisher Springfield Illinois
3 Godinho F S Chiconelli J R & Lemos C (1967) Desmoplastic fibroma of bone *J Bone Jt Surg* 49 B 560
4 Jaffe H L (1958) *Tumours and tumourous conditions of the bones and joints* Lea and Febiger Philadelphia
5 Scheer B E & Kuhlman R E (1963) Vertebral involvement by desmoplastic fibroma *J A M A* 185 121
6 Whitesides Th E & Ackerman L V (1960) Desmoplastic fibroma *J Bone Jt Surg* 42 A 1143

Table 3 Numbers and percentages of recurrent dislocations of a series of primary dislocations treated during a 3 year period (1962–1964)

Year of primary dislocations	Number of patients reviewed after primary dislocation	Number of recurrent dislocations up to 1966
1962	166	18 (11 per cent)
1963	189	15 (8 per cent)
1964	211	15 (7 per cent)
Total	566	48 (8 5 per cent)

Date of review February–June 1966

the 1964 group The true risk of recurrent dislocation is probably about 10–15 per cent Considering the high frequency of shoulder dislocation this percentage is important

This frequency is all the more important because recurrent dislocations are believed to occur mainly in the relatively low age groups According to *Ahrer* and *Biebl* recurrent dislocation occurs until the age of 35 according to *Hohmann* and *Gjores* until the age of 40 *McLaughlin* and *Rowe* claim that recurrent dislocation is rare after the age of 40 years Of our patients treated because of recurrent dislocation 73 2 per cent were men and 72 3 per cent were below 50 years The ratio of the rate of recurrence below 50 years to that above this age was 5 1 in men but 1 1 in women In 196 recurrent cases the ages of the patients at the time of the first dislocation were known The series contained 111 patients (57 per cent) below 30 years 12 1 per cent of 760 patients with primary dislocation were below 30 years

The tendency of dislocations to recur in the lower age groups has been reported by *McLaughlin* 1950 *Rowe* 1956 In our material every second patient below 20 years and every third in the 20–29 year group had a recurrence The corresponding rate for patients aged 30 or more was 1 out of 15 to 30 Judging from these figures recurrences are

Table 4 Age distribution of recurrent dislocations

Years	–20	21–30	31–40	41–50	51–60	61–70	71–80	81	Total
Primary dislocations	28	35	62	67	125	149	78	[illegible]	566
Recurrent dislocations	13	11	4	5	4	6	4	1	48

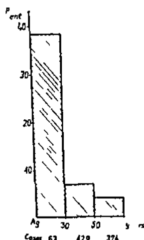


Figure 1 Age distribution of recurrences

much more common in patients below 30 years (Table 4) The significance was estimated by χ^2 test $P < 0.001$ Figure 1 gives the distribution of the groups of patients

Duration of immobilisation According to *Watson Jones*, immobilisation for a period of 3–4 weeks prevents recurrences The relation between duration of immobilisation and incidence of recurrence in the present series is given in Table 5

Table 5 Recurrences grouped according to duration of immobilisation after primary dislocation

Duration of immobilisation	0–7 days	8–14 days	15– days	unknown
Number of primary dislocations	121	342	64	39
Number of recurrences	19	22	3	4
Percentage of recurrences	16	6	4.5	10

Recurrent dislocation occurred in every sixth patient in whom the shoulder was not immobilised or immobilised for 3–7 days Among patients whose shoulder was immobilised for 8–14 days only every sixteenth had recurrent dislocation The number of shoulders immobilised for a longer period was too small to warrant any conclusion Since these groups did not differ substantially regarding the patients ages it appears that the incidence of recurrent dislocation varies with the duration of immobilisation ($P < 0.001$) The results are summarised in Figure 2

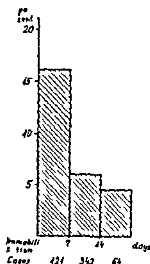


Figure 2 Recurrences grouped according to duration of immobilisation after primary dislocation

Occurrence of contracture It is well known that the shoulder is susceptible to contracture It is of special importance in the older age groups In our series of primary dislocations 408 cases were evaluated in this respect at the end of the treatment (Table 6) The results are given in Figure 3 Limitation of movement was significantly correlated with the patients ages ($P < 0.001$)

Table 6 Limitation of movement in relation to the age at end of treatment

	–30 years	31–50 years	51– years	Total
Number of primary dislocations	48	110	250	408
Number of patients with at least 90 limitation	1	16	94	111
Percentage	(2)	14	37	27

DISCUSSION

Opinions differ as to the cause of recurrent dislocation Many authors stress the importance of hereditary factors constitutional weakness or dysplasia of the joints It is known that in some cases the first dislocation occurs after an apparently trivial trauma It was reported in 4 per cent in Gjores series in 4 2 per cent of our series (Recurrent dislocations occurred in 69 per cent after trivial trauma) In our series among 535 cases of primary dislocations substantial trauma produced

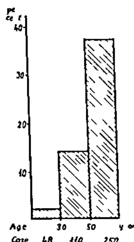


Figure 3 Age distribution of contracture of shoulder joint

a recurrent dislocation in 40 and trivial trauma in 27 cases produced a recurrent dislocation in 8

According to *Bankart* the injury followed by recurrences may differ in type from the remainder The mechanism of injury was studied by *Rowe* in a large number of cases but he could not confirm *Bankart* s hypothesis *Ehalt* also assumed some intermediate type besides the two types of dislocation (anterior and inferior)

Many authors emphasize irreversible anatomical changes produced by the first injury According to *Joessel* the joint cavity is increased three fold in habitual dislocations Thomas assumes the development of a bag on the capsule after the first injury and that the caput humeri dislocates into it on recurrent dislocation *Hermodson* suggests that primary dislocation causes an irreversible defect in the posterior lateral surface of the head *Diethelm and Hilscher* claim that this defect is pathognomic *Adams Hills* and *Sachs Palmer & Widen* have very often found this type of lesion in patients with recurrent dislocation *Rowe* has found this defect in 57 per cent after recurrent dislocation in 38 per cent after primary dislocation but also in about 10 per cent of healthy persons On the basis of these findings this defect might play a predisposing role Some of the authors attach great importance to the rupture of the labrum (*Bankart* s injury) which according to *Adam* s data can be found in 87 per cent of the cases with recurrent dislocation

Watson Jones and others (*K Speed Nicola Moseley*) feel that recurrence is due to unsatisfactory treatment After dislocation the

shoulder is usually immobilised for only a short period (not more than one week). It is obvious that ligamentous injury of the knee or the ankle will be followed by instability if the joint is not immobilised satisfactorily. *Watson Jones* stresses that the shoulder is built up in the same way and that if it is not immobilised satisfactorily dislocation may recur. Recurrent dislocation may therefore perhaps not be an unavoidable consequence of the injury but the result of inadequate treatment.

Our result are in agreement with *Watson Jones'* hypothesis. However, in the treatment of dislocation immobilisation for 3–4 weeks is not advisable in all cases. In an elderly patient the most important problem is the contracture of the shoulder and not the recurrent dislocation. It is therefore advisable not to treat old and young patients in the same way. In old age it seems wise to immobilise the shoulder for a short period and to apply functional treatment to prevent contracture. In younger persons (up to 30 years) immobilisation for at least 3 weeks suggested by *Watson Jones* appears indicated.

SUMMARY

The authors investigated the further course of shoulder dislocation in a series of patients (760 primary and 284 recurrent dislocations) treated at the Central Out-patient Department of the Injured of Budapest. They found an increase in the number of primary dislocations among elderly patients and mostly among women during the last decades.

They found a rate of recurrence of 8.5 per cent, but added that the true figure is probably as high as about 10–15 per cent. The recurrence of dislocations is significantly more common below 30 years of age. The frequency of recurrent dislocations is significantly lower when the joint is immobilised for an adequate period. In elderly patients contracture after the immobilisation of the joint is the most serious risk.

On the basis of their results they advise an immobilisation for 3 weeks if the patient is younger than 30 years, but for a short period if he is above 50 years of age. In this latter age group early physiotherapy is advisable.

RÉSUMÉ

Les auteurs ont étudié le pronostic des luxations de l'épaule. Les études furent basées sur une série de malades: 760 luxations primaires et 284 récidives. Tous ces malades ont été traités à la Polyclinique Centrale pour les accidentés de Budapest. Les auteurs ont trouvé que les luxa

tions primaires etaient plus nombreuses chez les personnes agees et sur tout chez les femmes tandis que les recidives etaient plus nombreuses au dessous de 30 ans La difference des manifestations au dessous et au dessus de 30 ans est tres signifiante Les auteurs ont trouve 8 5 p 100 de recidives parmi les luxations primaires Ils calculent que la pro portion reelle doit etre 10–15 p 100

Avec la prolongation de l immobilisation le rapport des recidives a éte diminue Chez les personnes agees le danger le plus redoutable c est la contracture de l epaule

En raison de ces resultats les auteurs recommandent une immobili sation – si le malade est au dessous de 30 ans – d au moins trois se maines tandis que chez ceux au dessus de 50 ans ils recommandent une immobilisation d une semaine au plus avec application le plus tot possible de la kinesothérapie

ZUSAMMENFASSUNG

Auf Grund eines dreijahrigen Krankenmaterials (1962–64) der Unfall stationszentrale Budapest (760 erste und 284 wiederholte Luxationen) untersuchten Autoren die Prognose der Schultergelenkverrenkung Sie fanden dass die Verhaltniszahl der älteren vor allem der Frauen in den letzten Jahrzehnten sich erhoht hat Sie fanden insgesamt in 8 5 Pro zent der ersten Verrenkungen eine wiederholte Luxation Gemäss ihrer Kalkulation ist aber das Verhaltnis aller widerholten Verrenkungsfälle zwischen 10 und 15 Prozent

Eine wiederholte Luxation kommt ofter in Alter unter 30 Jahren vor Der Unterschied zwischen Altersgruppen unter und über 30 Jahren ist stark signifikant

Mit Verlangerung der Ruhigstellung vermindert sich bedeutend die Verhaltniszahl der widerholten Luxationen In hoherem Alter ist aber nach Ruhigstellung die Kontraktur die Hauptgefahr

An Hand ihrer Ergebnisse empfehlen Autoren bei Patienten unter 30 Jahren eine Ruhigstellung fur mindestens 3 Wochen dagegen über 50 Jahren nach einer kurzdauernden Ruhigstellung eine fruhe aktive Bewegungsbehandlung

ACKNOWLEDGEMENT

We are indebted to *I Juvan* and *P Csaki* (Dept of Mathematics of the Hungarian Academy of Science) for statistical evaluation of our results

REFERENCES

Adams cit Watson Jones R

Ahrer F (1965) Die Traumatologie der Schulter *Klin Med* 20 101

Bankert A S B (1938) The pathology and treatment of recurrent dislocation of the shoulder joint *Brit J Surg* 26 23

Biebl R (1935) Behandlung und Prognose frischer Schulterluxationen *Arch orthop Unfall Chir* 35 381

Bruckner H (1966) Auswertung von 216 primaren und 50 habituellen Schultergelenkluxationen *Mschr Unfallheilk* 69 394

Burckle de la Camp H & Rostock P (1956) Handbuch der gesamten Unfallheilkunde *Bd III Enke Stuttgart*

Diethelm L & Hilscher W M (1954) Der Wert des Nachweises der typischen Impressionsfraktur nach Schultergelenkluxation *Mschr Unfallheilk* 57 353

Ehalt W (1950) Unfallchirurgie im Rontgenbilde Maudrich Wien

Frank L (1960) *Chir Praxis* 4 230

Gjores F F & Nilsonne U (1965) Prognosis in primary dislocations of the shoulder *Acta chir scand* 129 468

Hermodson cit Diethelm Hilscher

Hills & Sachs cit Rowe

Hohmann G Hackenbroch M & Lindemann K (1959) Handbuch der Orthopaedie Bd III G Thieme Stuttgart

Joessel cit Moseley

Konig F & Magnus G (1934) Handbuch der gesamten Unfallheilkunde *Bd III* Enke Stuttgart

McLaughlin H L & Cavallaro W U (1950) Primary anterior dislocation of the shoulder *Amer J Surg* 80 615

Moseley H F (1963) Shoulder lesions P B Hoeber New York

Nicola T (1949) Acute anterior dislocation of the shoulder *J Bone Jt Surg* 31 A 153

Palmer & Widén cit Rowe

Rowe C R (1956) Prognosis in dislocation of the shoulder *J Bone Jt Surg* 38 A 957

Speed K (1942) A textbook of fractures and dislocations IV Ed Lea and *Febiger* Philadelphia

Sommer cit Konig Magnus

Thomas cit Moseley

Watson Jones R (1956) Fractures and joint injuries Vol II Livingstone London Edinburgh

Acta orthop Scandinav 40 225–233 1969

From the Orthopaedic Clinic, Harnosand (Chief N Lindstrom, M.D.) Sweden

RECONSTRUCTION OF PROXIMAL HUMERUS BY MUSCLE-SLING PROSTHESIS

By

STEFÁN HARALDSSON

Received 6 ix.67

In surgical reconstruction of the proximal humerus after extensive resection of bone transplantation of autogenous fibula has long been the standard therapeutic measure (*Rovsing* 1910 *Borelius* 1914 *Skillern* 1920 *Albee* 1921 *Lexer* 1925 *Schauffler* 1926 *Hammond* 1926 *Behrend* 1930 *Clark* 1959 *Gilmer* 1963 *Goldberg* 1964 *Wilson & Lance* 1965)

Despite reports of satisfactory end results even after long observation (*Clark* 1959 *Goldberg* 1964) the method has proved to have certain disadvantages such as a tendency of the graft to fracture (*Hammond* 1926 *Schauffler* 1926 *Gilmer* 1963 *Wilson & Lance* 1965) and unsatisfactory reconstruction of the shoulder joint and the anatomy of the upper arm

In recent years various types of prostheses have been described to replace defects in the proximal humerus Most of these prostheses are designed to replace only the humeral head or part of it (*Krueger* 1951 *Richard Judet & Rene* 1952 *Neer* 1955) Other types of prostheses described in the literature and intended to replace a major part of the proximal humerus (*Ducci* 1963 *Lynn Alexakis & Bechtol* 1965 *Casuccio* 1966) have one feature in common *vi* like the fibula graft they do not allow satisfactory reconstruction of the tendo-capsular apparatus of the humero scapular joint or reliable reinsertion of the muscles attached to the proximal metaphysis and diaphysis of the humerus

At the orthopaedic clinic Harnosand we were confronted with this problem (*Haraldsson* 1966) in the treatment of a 22 year old woman with a progressive locally destructive tumour of the proximal part of the right humerus (Figure 1)

Histological examination of conventional biopsy specimens from the



Figure 1 Primary roentgenogram Osteolytic process with osteogenetic cortical reaction

interior of the cavity and affected part of the corticalis revealed no signs of malignant tumour The pathologist s report was connective tissue islands in bone tissue and exotosis In view of this favourable report and the fact that the results of all laboratory tests were normal the exostoses were removed and the cavity was curetted and filled with autogenous bone chips from the iliac crest Two new biopsy specimens removed at this operation were likewise found to contain no signs of malignancy

Later follow up however revealed progressive destruction of the proximal humerus (Figure 2) and loss of function

Biopsy specimens were then removed from altogether 3 parts of the tumour but none of them showed evidence of malignancy

Because of the progression of the tumour and the local destruction it was decided to resect the tumour with a broad safety margin of healthy tissue which implied almost hemiresection of the humerus with removal of the proximal 14 cm of the bone whose original total length was 31 cm This required a prosthesis allowing reconstruction of the tendocapsular apparatus of the humeroscapular joint with reinsertion of all together 9 muscles attached to the proximal humerus



Figure 2 Progression of tumour with destruction of proximal humerus

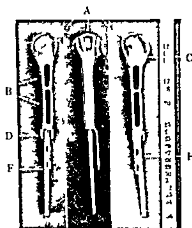


Figure 3 Muscle sling prosthesis A Perforations for sling fixation of muscles of rotator cuff to each other B Canals for sling fixation of muscles of metaphysis and diaphysis C Eyes for extra fixation D Flange preventing rotation E Plate for subperiosteal fixation F Self locking intramedually shaft

It was realised from the beginning that the effect of direct suturing of these muscles to a metal body would only last as long as the sutures held which in view of the wear and tear would presumably be only for a limited period

It was at last concluded that suturing of the muscles preferably antagonists to one another through specially made perforations in the prosthesis would provide a permanent muscle sling fixation The prosthesis was designed by the author on the basis of roentgenograms of the affected and contralateral side and was produced in vitallium by The Austenal Company New York (Figure 3)

While waiting for the prosthesis the patient became pregnant Since all together 7 biopsy specimens had shown no signs of malignancy it was decided to grant the patient s request to postpone the operation until after delivery The patient was therefore operated upon 8 months



Figure 4 Preoperat ve r entg n gram

later than originally intended Preoperatively her general condition was good the results of all laboratory tests were normal and there were no signs of metastases Her right shoulder joint was stiff swollen tender and aching The preoperative roentgenogram taken 4 years after first examination is given in Figure 4

SURGICAL TECHNIQUE

Exposure through Henry s approach (*Henry* 1959) The tumour was well defined against the surrounding soft parts The subscapularis supra spinatus infraspinatus and teres minor muscles were divided together with the joint capsule and the long head of the biceps muscle This enabled exarticulation The axillary (circumflex) nerve and the posterior circumflex artery were partly embedded in tumour masses from which they were freed without injury The pectoralis major latissimus dorsi and teres major muscles were divided and the proximal part of the lateral and medial heads of the triceps muscle were loosened from

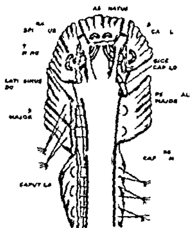


Figure 5 Diagrammatic representation of the technique of muscle reinsertion on the muscle sling prosthesis The supraspinatus infraspinatus teres minor and subscapularis muscles are fixed to one another and the prosthesis by tendon transplants through perforations in the region of greater tuberosity of the prosthesis The tendon transplants are taken from the long extensors of the 3rd and 4th toes The latissimus dorsi and teres major are sutured to the pectoralis major muscle in the proximal diaphyseal canal of the prosthesis The proximal part of the lateral head of the triceps is fixed to the corresponding part of the medial (deep) head of triceps in the distal diaphyseal perforation The long head of the biceps muscle is divided drawn through one of the holes in the prosthesis resutured and fastened to the tendon graft

bone The proximal third of the insertion of the deltoid was also loosened This muscle thus retained the major part of its insertion on the intact part of the humerus after division of the diaphysis with a broad margin of macroscopically healthy bone The prosthesis was inserted in the remaining part of the humerus after a slit had been sawn in the bone in the frontal plane for fixation of the flange of the prosthesis to prevent it from rotating The reinsertion of the muscles on the prosthesis is illustrated in Figure 5

Postoperative treatment consisted of 6 weeks immobilisation of the limb in a thoraco brachial splint followed by physiotherapy of the muscles and joints

When last seen 9 months after the operation the shoulder no longer ached and even movement of the arm was practically painless The muscles of the right shoulder were still somewhat weak and the range of movement of the joint was still reduced but both sequelae were improving The strength of the muscles of the right elbow wrist and hand were satisfactory The strength of the grip of the right hand as measured dynamometrically was thus 4 kg The corresponding figure for the left hand was 5 kg The patient s general condition was good The E S R was normal and there were no signs of metastases or of a local recurrence The patient is right handed and has no difficulty in using a knife and fork or in washing and dressing and does most of the work in a household of 3 persons The range of movement of the operated shoulder at last follow up is shown in Figure 6

In the roentgenograms taken at the review the prosthesis appeared to be firmly anchored in the residual part of the humerus The congruence between the articular surface of the prosthesis and the glenoid

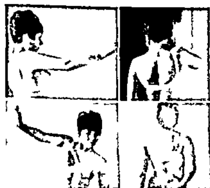


Figure 6 Range of motion at review No neurological or vascular disturbances No measurable atrophies except for 1 cm atrophy of right forearm



Figure 7. Roentgenograms at review. Prosthesis anchored in distal humerus. Congruence in humero-scapular joint.



Figure 8. Abduction. No change in congruence in joint. No tendency to subluxation between prosthesis and glenoid cavity.

cavity appeared normal without any signs of subluxation during rest or movement (Figures 7 and 8).

Pathological examination of the excised tumour revealed that parts of the lesion had become malignant and now showed the histological picture of juxtacortical (parosteal) osteogenic sarcoma. The margin of resection showed no signs of tumour.

This rare neoplasm (less than 5 per cent of osteogenic sarcomas: *Dahlin* 1957, *Aakhus, Eide & Stokke* 1960) is distinctly less malignant than the ordinary osteogenic sarcoma (*Dwinnell, Dahlin & Ghormley* 1954, *Lichtenstein* 1965) and the question of treatment is still a matter of certain controversy.

Since the resection was believed to have been radical, further active measures were refrained from. The patient is being carefully followed up.[1]

---

1 Since submitting this manuscript for publication several controls have been made — 2½ years post op. the prosthesis showed no signs of loosening or breaking. Function was satisfactory. Radio-opaque spots had appeared in the scar. They were excised. Histological examinations showed no certain evidence of malignancy.

COMMENT

Though the patient has only been followed up for a relatively short time the preliminary results obtained with the prosthesis appear to warrant the conclusion that a muscle sling prosthesis of this general design is worth a further trial The method of reinsertion of the muscles to the prosthesis near their original site of insertion by slings through perforations in the prosthesis is supposed to provide permanent fixation of the muscles that part of the perforations not occupied by the muscle slings presumably being filled with scar tissue Because of the insertion of the muscles in the prosthesis itself the force of muscle pull is distributed in a more normal way over both the prosthesis and the parts distal thereto This might mean that the risk of fracture or loosening of the prosthesis would be smaller than when the inserted material graft or prosthesis functions only as a lever over which the muscles inserted distally to the prosthesis exert their pull Moreover the prosthesis is suspended in muscles which probably reduces the tendency to subluxation

This prosthesis might be improved by deeper perforations extending further medially in the area of greater tuberosity of the prosthesis This would facilitate reinsertion of the muscles of the rotator cuff as well as the passage of the head of the prosthesis under the acromion

In cases where a still larger portion of the humerus must be sacrificed one might create a muscle sling between the deltoid and the coraco brachial muscles by means of a supplementary perforation situated more distally in the diaphysis of the prosthesis

SUMMARY

A description is given of a muscle sling prosthesis designed to replace large defects after extensive resection of the proximal half of the humerus The muscles are reinserted by fixing them to one another through openings in the prosthesis which is supposed to provide permanent fixation of muscles to prosthesis

The preliminary clinical and roentgenological results are encouraging

RÉSUMÉ

Il est donne une description d une prothese de soutien des muscles destinee a remedier a de larges manques à la suite d une resection extensive de la moitié proximale de l humérus Les muscles ont été

réinserés en les fixant les uns aux autres à travers les ouvertures pratiqués dans la prothèse afin d'assurer une fixation permanente des muscles a la prothèse

Les resultats cliniques et radiologiques sont encourageants

ZUSAMMENFASSUNG

Eine Beschreibung einer Muskelschlingeprothese wird gegeben die konstruiert wurde um grosse Defekte nach ausgedehnter Resektion der proximalen Humerushälfte zu erstatten Die Muskeln werden von neuem *befestigt indem sie zueinander mittels Öffnungen in der Prothese fixiert* werden und man will dadurch eine dauernde Fixierung der Muskeln an die Prothese schaffen

Die vorläufigen klinischen und röntgenologischen Ergebnisse sind ermutigend

REFERENCES

1 Aakhus T Eide O & Stokke T (1960) Parosteal Osteogenic Sarcoma *Acta radiol* 54 29–40

2 Albee F H (1921) Restoration of Shoulder Function in Cases of Loss of Head and Upper Portion of Humerus *Surgery* 32 1–19

3 Behrend M (1930) Transplantation of the Head and Shaft of the Fibula to the Humerus *Surg Gynec Obstet* 51 717–719

4 Borelius J (1914) Beiträge zur Osteoplastik *Beitr Klin Chir* 89 ?14 ?30

5 Casuccio C (1966) Internal Prostheses of the Upper Limbs SICOT, 10th Congress Paris Sept 4–9

6 Clark K (1959) A case of Replacement of the Upper End of the Humerous by a Fibular Graft Reviewed after Twenty nine Years *J Bone Jt Surg* 41 B 36?–368

7 Dahlin D C (1957) Bone Tumors Springfield Illinois C C Thomas

8 Ducci I (1963) Sostituzione endoprotesica di estesa lesione omerale in granulomatosi eosinofila atipica *Arch d Centr Traum Ortoped dell Instituto Nazion Infort* 3 1–18

9 Dwinnell L A Dahlin D C & Ghormley R K (1954) Parosteal (Juxtacortical Osteogenic Sarcoma *J Bone Jt Surg* 36 A 73? 744

10 Francis K C & Worcester J N (1962) Radical Resection for Tumors of the Shoulder with Preservation of a Functional Extremity *J Bone Jt Surg* 44 A 1423 1430

11 Gilmer W S (1963) In Campbell s Operative Orthopaedics ? Ed 4 p 1254 1?5 Saint Louis The C V Mosby Co

12 Goldberg D (1964) Autogenous Replacement Prosthesis for the Head of the Humerus Chondrosarcoma of Humeral Head *Bull Hosp Joint Dis (NY)* 25/1 ?6–84

13 Hammond R (1926) Transplantation of the Fibula to Replace Bony Defect in the Shoulder Joint *J Bone Jt Surg* 8/3 627 635

14 Haraldsson S (1966) Reconstruction with Prosthesis after Hemiresection of Humerus Meeting of Swedish Orthop Ass held on Dec 3 Stockholm
15 Henry A K (1959) Extensile Exposure Edinburgh and London Livingstone
16 Krueger F J (1951) A Vitallium Replica Arthroplasty on the Shoulder *Surgery* 30 1005–1011
17 Lexer E. (1925) Joint Transplantations and Arthroplasty *Surg Gynec Obstet* 40 782–809
18 Lichtenstein L. (1965) Bone Tumors Saint Louis C. V Mosby
19 Lynn T A Alexakis P G & Bechtol C. O (1965) Stem Prosthesis to Replace Lost Proximal Humerus *Clin Orthop* 43 245–247
20 Neer C. S (1955) Articular Replacement for the Humeral Head. *J Bone Jt Surg* 37 A 215–228
21 Richard A Judet R. & Rene L. (1952) Reconstruction prothetique acrylique de l extremité superieure de l humerus specialement au cours des fractures luxations *J Chir* 68 537–547
22 Rovsing T (1910) Et Tilfælde af fri Knogletransplantation til Erstatning of Overarmens øverste to Trediedele ved Hjælp af Patientens Fibula. *Hospitalstidende* 53 7–17
23 Schauffler R. M (1926) Transplant of the Upper Extremity of the Fibula to Replace the Upper Extremity of the Humerus *J Bone Jt Surg* 8/4 723–726
24 Skillern P G (1920) Sarcoma of Humerus Resection of Upper Shaft with Transplantation of Upper Third of Fibula to Humerus Stump *International Clinics* 1 41–44
25 Wilson P D & Lance E M (1965) Surgical Reconstruction of the Skeleton Following Segmental Resection for Bone Tumors *J Bone Jt Surg* 47 A 1629–1656

Acta orthop Scandinav 40 234-236 1969

From the Department of Obstetrics and Gynaecology General Hospital Malmö Sweden (Head Prof S Kullander MD) and the Department of Surgery Centrallasarettet Karlskrona Sweden (Head E. Landelius MD)

A METHOD FOR THE TREATMENT OF HUMERUS FRACTURES IN THE NEWBORN USING THE S von ROSEN SPLINT

By

BIRGER ÅSTEDT

Received 9 ix 6

Peripheral fractures in the neonatal period are almost always complications of the delivery Fractures of the clavicle and humerus are the most common followed by femur fractures and very occasionally epiphyseal dislocation of the humerus and femur or lower leg fractures

These fractures are not of the greenstick type and the deformities are often severe Healing takes place rapidly with good callus formation Significant malalignment can be corrected during healing an angle of up to 40–50 per cent in a humerus may be reduced later (1)

Many consider that even unreduced fractures in the newborn heal with good results This is however not entirely true Madsen (2) who followed up a large series in Copenhagen found that despite adequate healing there were shortening and rotation deformities in several cases which could even be demonstrated 30 years later

There is no reason why adequate correction of the fracture should not be undertaken from the beginning to avoid these complications Splinting gives good immobilization but must usually be combined with *traction to give a good position (2) The problem here is often how to* hold the child against the pull of the traction *Watson-Jones (4)* "frame with a loop over the infant's body is satisfactory for femur *fractures* but humerus fractures still present a problem

The author has obtained good results in 5 cases by using the splint described by *S von Rosen* (3) for the treatment of congenital dislocation of the hip joint This can in turn be fixed to the bed and the infant is thus held in position (Figures 1 and 2) A great advantage of this



Figure 1 S. von Rosen splint fixed to the bed with a sling



Figure 2 Child with bilateral fractures of the humerus held in traction with the aid of S. von Rosen splint

technique is that nursing is relatively easy, the changing of nappies for instance can be carried out without interfering with the traction

The traction is applied to the wrists over a foam rubber gauntlet, variable loads—usually 50–100 cc water in a plastic bag—can then be applied in the usual way over a pulley as necessary in order to correct the deformity. Lateral traction is occasionally performed but then control is more difficult. Better and more natural is the direct distal pull (Figure 2) analogous with the treatment of adult fractures with hanging casts.

Flexion at the elbow has been suggested to prevent rotation deformities but in this technique the natural and correct position is automatically obtained due to the free rotation of the traction at the wrist.

A further advantage of this technique is that X-ray control may easily be performed and should be undertaken at short intervals due to the rapid rate at which healing takes place. Humerus fractures are stable after 10–14 days.

SUMMARY

Fractures of the humerus in the neonatal period are not of the green stick type and malalignment is often considerable Although corrections are easily performed during the healing period a good position should be sought from the beginning Traction is preferred to splinting but it is often difficult to hold the child against the pull of the traction Most of the previously described techniques are complicated and uncomfortable for the child A technique is described here whereby the child is held in a von Rosen splint [1] this enables simple correction of the deformity while at the same time permitting extremely easy nursing and X-ray control as necessary

REFERENCES

1 Blount, W P (1955) *Fractures in children* Williams & Wilkins Co., Baltimore
2 Madsen T E (1955) *Acta obstet gynaec scand* 34 41
3 von Rosen S (1957) *Acta orthop scand* 126 26
4 Watson-Jones R. (1952) *Fractures and joint injuries* E. & S Livingstone Ltd. Edinburgh and London

[1] S von Rosen splint is made in the Orthopaedic Department Malmo General Hospital, and also by Zimmer Orthopaedic Ltd. Bridgend Glam., Wales

Acta orthop Scandinav 40 237–245 1969

From the Orthopaedic Clinic, Karolinska Institutet Stockholm
(Head Professor S Friberg)

VERTEBRAL EPIPHYSEODESIS OF THE THORACIC CURVE IN THE OPERATIVE TREATMENT OF IDIOPATHIC SCOLIOSIS

By

ULF NILSONNE

Received 6 iii 68

It seems logical to suppose that a progressive scoliosis can be inhibited by arresting growth through vertebral epiphyseodesis on the convex side of the scoliotic curve Ideally the growth potential in the remaining vertebral epiphyses on the concave side would cause the curve to straighten out Scoliosis has been produced in animal experiments by unilateral arrest of vertebral growth (*Haas* 1939 *Pacher* 1939 *Nachlas & Borden* 1950) and has even been made to regress by subsequently destroying the remaining epiphyses on the convex side (*Nachlas & Borden* 1951) In clinical work *Roaf* (1963) in particular has employed surgical control of growth in the treatment of scoliosis Using a dorsal approach and costo transversectomies he combines vertebral epiphysectomies on the convex side with fusion Roaf reports that the scoliosis was arrested in all the operated cases while in about half the deformity has even been reduced

In an earlier paper (*Nilsonne* (1964) I emphasized the advantage of the transthoracic approach for vertebral epiphyseodesis which has also been pointed out by *Le Coeur & Charleux* (1960) The thoracotomy gives the surgeon a very good picture of the deformation of the thoracic spine and makes the vertebral bodies readily accessible The operation involves chiselling out—on the convex side of the scoliosis—the epiphyseal plates in the 4–5 vertebral bodies that correspond to the main part of the scoliotic curve The intermediate discs are resected to half the depth of the vertebral bodies but fusion of the vertebrae is not used (Figure 1)

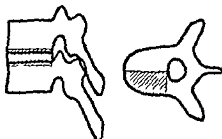


Figure 1 Schematic drawing representing the extent of the vertebral epiphysectomies

MATERIAL AND METHODS

The operation described was performed on 11 patients with idiopathic scoliosis in whom the primary curve was located in the thoracic spine All the patients were female aged 8–14½ years at the time of the operation The pre operative period of observation varied from 6 years to 6 months A few of the patients had been treated with a plaster bed but most of them were untreated Active correction of the scoliosis had not been tried before the present operation the indication for which was rapid progression of the scoliosis during the past three months as demonstrated roentgenologically Risser's sign was used as an indication that the longitudinal growth of the spine was not yet complete In no case were the iliac apophyses found to have capped at the pre operative X ray examination

In all the patients but one the scoliotic curve was convex to the right In case 7 in which the curve was convex to the left the thoracotomy had to be performed from the left side and it was feared that the location of the heart and the aorta would make it difficult to get at the vertebral bodies It transpired however that the heart and the great vessels had a central position in the mediastinum and had not been dislocated by the scoliosis There was consequently no difficulty in performing the epiphysectomies

The patients were allowed up on the 3rd 5th postoperative day They were discharged from the hospital after 3–4 weeks and were able to return to school 6 8 weeks after the operation Cases 1–10 did not receive any special postoperative treatment in the form of physiotherapy a brace or the like In case 11 the patient was given a Milwaukee brace (fitted before the operation) for continuous use

The patients were checked up with a clinical and X ray examination every 3rd month to start with subsequently twice a year The interval between the operation and the last examination varies between 11 months and 6 years As will be seen from Table 1 most of the patients had reached such a mature age by the time of this follow up that further progression of the scoliosis could be ruled out

RESULTS (Table 1)

No serious complication developed either during the operation or subsequently In one case a superficial infection arose in the anterior part of the thoracotomy incision The wound nevertheless healed with

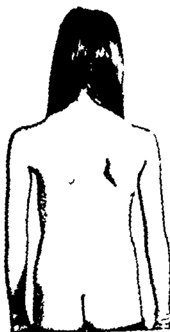
Table 1 Clinical data in 11 operated cases of idiopathic scoliosis

Case No	Observation time before operation years	Age at operation years	Levels of epiphysectomies	Apex of curve	Degree of curve: before operation	Degree of curve: at follow up	Degree of curve: gain + loss —	Standing height cms: before operation	Standing height cms: at follow up	Standing height cms: gain	Age at follow up	Capping of iliac apophyses years after operation
1	1 2/12	14 1/12	Th V–Th IX	Th VII	73	89	—15	[illegible]	160	1	20	2
2	6	13 8/12	Th V–Th IX	Th VIII	74	105	—31	140	147	7	19 8/12	3
3	1 6/12	11 10/12	Th V–Th X	Th VIII	37	37	±0	152	157	5	17 6/12	1 6/12
4	3/12	12 2/12	Th VI–Th X	Th VIII	50	44	+6	152	156	4	16 9/12	3
5	1	11 7/12	Th VI–Th X	Th VIII	40	47	—7	159	167	8	16 1/12	3
6	1	14 3/12	Th V–Th X	Th VIII	54	58	—4	160	162	2	18 3/12	1 6/12
7	9/12	12 9/12	Th VIII–Th XI	Th IX	70	65	+5	150	156	6	16 [illegible]/12	2
8	1	8 9/12	Th V–Th IX	Th VII	42	60	—18	133	150	17	11 10/12	no capping
9	3 6/12	11 7/12	Th V–Th IX	Th VII	72	102	—30	143	143	0	14 4/12	2
10	6/12	7 11/12	Th VI–Th IX	Th VIII	36	60	—24	131	142	11	10 8/12	no capping
11	5	12 1/12	Th VII–Th X	Th IX	46	25	+21	140	146	6	13	11/12


V







a cosmetically acceptable scar The patients had typical thoracotomy pains during the first postoperative day True back pains were not experienced either in the postoperative period or later In some of the more pronounced cases of scoliosis moderate insufficiency symptoms in the form of fatigue appeared later in the period of observation

There was some loss of mobility in all cases particularly in respect of the lateral flexions that corresponded to the operated region This loss was moderate as a rule but in cases 2 and 9 complete rigidity was noted at the follow up examination

A histological examination was made of the resected epiphyseal plates and the discs This confirmed that the epiphyseal plates had been excised to the desired extent in all cases Nothing abnormal was observed in the epiphyseal plates or adjacent osseous tissues The disc specimens also presented a normal histological structure

The degree of scoliosis measured according to *Cobb* (1948) is given in Table 1 Pre operatively there were 2 cases with less than 40 (mild) 5 between 40 and 60 (moderate) and 4 with more than 60 (severe) After the operation a reduction of the scoliosis was noted in three cases This improvement was very marked in case 11 with a gain of 21 and a visible straightening of the thoracic spine (Figure 2) In cases 4 and 7 however the gain was only slight—about 5 —and was not outwardly visible The degree of scoliosis remained unchanged in case 3 while it progressed in the other seven cases In two of the latter (cases 5 and 6) the deterioration was slight and not outwardly visible The increase of the scoliosis measured in the other cases varied between 15 and 30 resulting in a pronounced thoracic deformity in cases 2 and 9

Capping of the iliac apophyses occurred an average of 2 years after the operation in 9 patients which means that the spine continued to grow longitudinally during this period In 2 patients (cases 8 and 10) capping of the iliac apophyses had not occurred at the time of the follow up study

DISCUSSION

During the period from which the present cases are taken 358 patients with idiopathic scoliosis attended the orthopaedic clinic The

Figure 2 Left Case 11 before operation Thoracic s [illegible] Right [illegible] ase 11 months after epiphyseodesis on the convex side of [illegible] T [illegible] 7 T [illegible] 10 Scoliotic curve reduced to [illegible] Note the marked improvement [illegible] appearance of the [illegible]

scoliosis was slight or moderate in the great majority of these patients and did not call for special treatment. Vertebral epiphyseodesis was the only type of operative treatment considered. The 11 operated cases comprise 3 per cent of the total number of idiopathic scoliosis. This frequency is in good agreement with *Cobb's* (1958) opinion that only a very small proportion of scoliosis cases require operative treatment.

An analysis of the effect of the epiphyseodeses in cases 1–10 gives a disparate picture. A minor improvement was noted in some cases, a minor deterioration in others. The values given for the change in the scoliosis must be judged with caution however, owing to the difficulty of applying the methods of measurement exactly and the fact that it is not easy to obtain identical projections at the various X-ray examinations. I therefore consider it most correct to regard cases 3–7 as unimproved. A more positive assessment would be that the epiphyseoctomies prevented or curtailed further progression. In cases 1–2 and 8–10, on the other hand, there was a slight—severe increase in the lateral curve and in these cases the epiphyseoctomies did not affect the progression of the scoliosis. *Le Coeur & Charleux* report that all 7 assessable cases out of 14 operated with epiphyseodesis displayed an improvement of the scoliosis though they do not specify the degree of correction. Their cases, moreover, differ from the present ones in that they were paralytic scolioses and that correction with plaster was used postoperatively.

It is not easy to determine which factors are responsible for the variety of the results in cases 1–10. Since capping of the iliac apophyses had not occurred in any of the cases before the operation, it was to be expected that the vertebrae would continue to grow. It has been calculated (*Tupman* 1962) that for girls in the age groups with which we are concerned here, the annual increment to the height per vertebral body is 1.5 mm. If growth is completely blocked on the convex side of five vertebral bodies, the concave side would have a total relative increase in height of 7.5 mm per annum provided its epiphyses functioned normally. Such a small increment naturally has less effect on a scoliotic curve as the subject approaches the termination of growth. On the other hand, the relationship between longitudinal growth and progression of the scoliosis is very irregular in these operated cases. Cases 2 and 7, for instance, both had a pre-operative scoliosis angle of about 70° and roughly the same total growth. But whereas the scoliosis progressed markedly in the former case, it regressed if anything in the latter.

It was disappointing to find a deterioration in cases 8 and 10 which had been operated on as early as in their 9th year. Theoretically it is just in these cases that the chances of improvement were greatest. A possible explanation is that the epiphyseal plates on the concave side did not have a normal function. It has been shown by *Blount* (1949) and others that blockade of an epiphysis inhibits the growth in this. In the disbalanced scoliotic spine there is probably increased pressure on the epiphyses of the concave side. After the epiphysectomies on the *convex side* growth on the concave side may be too weak to result in any correction.

Another possible explanation of the progression is that the epiphysectomies were performed in too few levels. The problem here however is that the epiphysectomies involve ligature of the intercostal arteries which also supply the spinal medulla. While the collateral circulation in the spinal medulla is manifestly sufficient to compensate for the arterial supply being cut off on one side of a limited number of segments, a more extensive unilateral closure of the arterial flow might endanger the function of the spinal medulla. This problem requires further study.

There is no doubt, on the other hand, that the epiphysectomies performed were sufficiently radical in each vertebra. The good view of the operation field made it easy to ensure that the epiphyseal plates were resected to half the depth of the vertebral body, while the microscopic examinations confirmed that the resection was sufficiently radical in a cranio-caudal direction. One can therefore rule out the possibility that epiphyseal remains on the convex side of the operated region were responsible for the progression of the scoliosis.

Ponseti & Friedman (1950) report that the higher an idiopathic scoliosis is located in the thoracic spine, the worse the prognosis. The present cases show a similar tendency. Scolioses with the apex in the region Th 7–Th 8 generally responded less to the epiphysectomies than those with the apex in the region Th 8–Th 9. This may indicate that the structure of the scolioses, besides being influenced by the control of growth, is also subject to other biomechanical factors that are difficult to define at present.

An undisputable pronounced correction of the scoliosis was obtained in Case 11. This differed from the other cases in that the patient was treated postoperatively with a Milwaukee brace, the intention being to apply a continuous distractive force against the spine and thereby relieve the pressure of the epiphyseal plates on the concave

side The internal control of growth was thus combined with external control mechanism The favourable effect seems to support this hypothesis and justifies further attempts

In this context one can consider whether the concave side of the scoliosis should not be relieved for some time before the operation as well for instance by means of a Milwaukee brace An extra stimulation of growth on the concave side before the operation might possibly help to produce a more rapid effect from the epiphysectomies on the convex side

Finally, it is worth pointing out that the transthoracic approach involves only a moderate trauma for the patient Fusion operations on the other hand generally involve a considerable surgical trauma and a danger of shock even when they are undertaken in several seances Furthermore compared with the prolonged pre and post-operative treatment with plaster that is required for fusion operations the total period of hospitalization is considerably shorter for vertebral epiphyseodesis and the subsequent treatment is also less complicated

To sum up the results in the present cases seem to show that progression of the scoliosis can be prevented in some cases simply by operative treatment in the form of vertebral epiphyseodesis on the convex side The effect is unpredictable however, and the possibility of further deterioration cannot be ruled out in the individual case Combined with external correction for instance a Milwaukee brace this type of operation may be able to make a scoliosis reversible

SUMMARY

Eleven cases of idiopathic scoliosis were treated with an operation involving vertebral epiphyseodesis on the convex side after thoracotomy A pronounced and lasting reduction of the scoliosis was achieved in the only case that was treated postoperatively with a Milwaukee brace In the other 10 cases in which postoperative correction was not attempted the scoliosis stopped progressing in 5 cases but deteriorated in the other 5 becoming considerably worse in two The reasons for these contradictory results are discussed

REFERENCES

Blount W P & Clarke G R (1949) Control of Bone Growth by Epiphyseal Stapling *J Bone Jt Surg* 31 A 464

Cobb J R (1948) Outline for the Study of Scoliosis Instruct Course Lectures *Amer Acad Orthoped*

Cobb J R. (1958) Scoliosis Quo Vadis? *J Bone Jt Surg* 40 A 507

Haas S (1939) Experimental Production of Scoliosis *J Bone Jt Surg* 37 963

Le Coeur P & Charleux. H. (1960) L abord direct du rachis Sa place dans le traite ment des scolioses. *Rev Chir Orthoped* 46 595

Nachlas W & Borden, J (1950) Experimental scoliosis—the role of the epiphysis *Surg Gyn Obst.* 90 672.

Nachlas W & Borden, J (1951) The cure of experimental scoliosis by directed growth control. *J Bone Jt Surg* 33 A 24

Nilsonne U (1964) Transthoracic approach for vertebral epiphyseodesis *Acta orthop scand* 34, 37

Pacher W (1939) Operative Erzeugung einer Skoliose im Tierversuch *Z Orthop* 69 140

Ponseti I V & Friedman B (1950) Prognosis in idiopathic scoliosis *J Bone Jt Surg* 32 A 381

Roaf R. (1963) The late results of unilateral growth arrest of the spine for scoliosis *Acta orthop scand* 33 393

Tupman E. S (1962) A study of bone growth in normal children and its relation ship to skeletal maturation *J Bone Jt Surg* 44 B 4?

Severe displacement includes 23 cases with the head of the radius displaced more than half the breadth of the bone and/or angulated more than 45. Slight displacement includes 25 cases with displacement less than in the former group and in 2 cases there was no visible displacement

Table 1 Distribution of fractures of proximal end of radius according to primary displacement type treatment and result of reduction

Site of fracture	Neck of radius 50						Head of radius 5	Total 55
Primary *displacement*	No 2		Slight 25		Severe 23		Slight 5	55
After reduction	No 2	No 1	Slight 24	No 5	Slight 6	Severe 12	Slight 5	55
Type of treatment								
None or unknown			2					2
Immob in splint	2		17			5	3	2
Closed reduction + immob		1	3	4	4	3	1	16
Open reduct.				1	4	3		5
Traction			2			1	1	4
Excision						1		1

The therapy is clear from Table 1 The most commonly used therapy was immobilisation in splint without any reduction This method has been used even in severely displaced fractures totally in 50 per cent of the cases

Closed reduction and immobilisation was used in 16 cases open reduction in 5 and traction in 4 cases Excision of the radial head was performed in one case and the result of reduction according to the clinical findings is classified as bad

The reduction is difficult and only 12 fractures were less displaced after reduction whereas 41 remained unreduced

The reduction was generally performed with the patient in general anesthesia, the elbow in extension pressed in varus and by digital pressure the operator tried to reduce the head of the radius which was usually displaced radially Immobilisation was performed with a plaster or cardboard splint with the elbow flexed 90 for 4-5 weeks

Primary complications such as nerve or vessel injuries did not occur In one case a paralysis of the ulnar nerve was noted after an open reduction The nerve re

covered in the course of 3–4 years and at after examination no difference in finger grips sudomotor function or two point discrimination could be measured. In one case the fracture was primarily poorly reduced and the mobility impaired. The head of the radius was removed in another hospital nine years after the accident. After that there was pain in the ulnar part of the arm and an ulnar paralysis developed. The ulnar nerve was transposed to the anterior side and then the pain vanished. Two-point discrimination was 1 mm wider in the little finger on the injured side than on the healthy one The force was not diminished

METHODS

All roentgenograms made between 1930 and 1950 at the Children s Hospital Gothenburg were re-examined and all cases with elbow fractures or dislocations were selected and registered. 60 per cent of the patients with fractures of the head or the neck of the radius were after examined clinically and roentgenologically by the author 1961–62 28–11 years after the accidents

At personal after examination the subjects were interviewed regarding the cause of the fracture, what they were doing at the time of the accident severity of the trauma and present sensation of pain sensibility disorders and decreased working capacity if any

Maximal flexion and extension pronation and supination were measured on both arms as well as carrying angle and circumference of upper and lower arms All angles were measured going out from the position of the humerus as zero flexion and extension on the dorsal side of the arm carrying angle on the ulnar side and pronation and supination as the position of the hand compared to that of the vertically held humerus.

Frontal and lateral Roentgen pictures were taken of both elbows Frontal views were taken with the elbow extended and the lower arm supinated with the volar aspect facing the Roentgen tube Lateral views were taken with the elbow flexed at right angles and the forearm supinated and one picture with the forearm pronated.

The position and range of motion of the elbows were noted in 100 sex and age matched children and 50 adults without known fracture in their histories were used as controls The healthy arm in each subject was also used as control

RESULTS

The incidence of fracture of the proximal end of the radius was compared to an approximate average population in the age group in Gothenburg of 60050 children during the time investigated A mean of 4 3 fractures were treated annually and thus per 1000 of average population up to the age of 15 0 07 fractures were treated annually The mean age was 9 7 years in boys 9 8 in girls 9 5 years In fractures of the neck the mean age was 9 3 years in fractures of the head of the radius the mean age was 12 6 years

According to *Ruckensteiner* (1931) the epiphysis of the head of the radius is visible in the Roentgen picture earliest at the age of 3 and

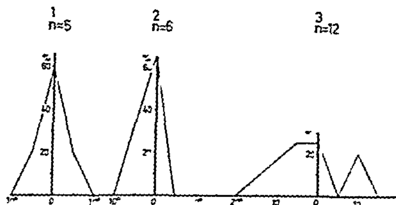


Figure 2 Difference in carrying angle between injured and uninjured arms in severely displaced fractures of the neck of the radius 1) no displacement after reduction 2) slight displacement after reduction 3) severe displacement after reduction + indicates varus on the injured side as compared to the uninjured arm

is fusing with the rest of the bone at 14–18 years of age earlier in girls than in boys

The carrying angle of the healthy arm in this material was on the average 159° whereas this angle in the controls and in the healthy arm in all other types of elbow fractures was 162 The difference is significant The difference in carrying angle between the injured and uninjured arms varied only between + 10° and — 15 most among the severely displaced fractures Their distribution is seen in Figure 2 where the percentage of difference between the healthy and the injured arms is represented split into groups according to result of reduction

Flexion and extension vary little after these fractures and only the severely displaced fractures impaired these movements *Compare* Figure 3 where the difference in movement is represented in relation to displacement Pronation and supination are very vulnerable to injuries in the proximal end of the radius which is clear from Figures 4 5 6 and 7 *showing difference in ability to pronate and supinate between* healthy and injured arms after severely displaced fractures The fractures without displacement did not impair the movements The slightly displaced fractures with remaining displacement impaired pronation by 20 in one case and by 10 in one Supination was impaired by 10 in one case

Working capacity in relation to the primary injury and result of reduction is given in Table 2 Only 2 patients had severe symptoms 11 had mild symptoms

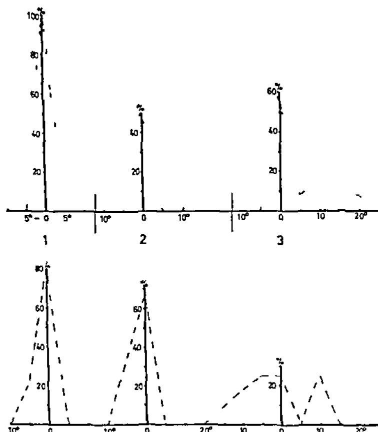


Figure 3 Difference in flexion (above) and extension (below) between injured and uninjured arms in severely displaced fractures of the neck of the radius 1) No displacement 2) slight displacement 3) severe displacement after reduction + indicates a more obtuse and — a more acute angle in the injured arm as compared to the contralateral one

Remoulding of the bone plays an important part in the prognosis after fractures in children This is true also in this group as is clear from Table 4 which shows the position of the fragments at the beginning and after the treatment as well as at after examination

Among the fractures of the head of the radius no displacement was found at the after-examination The 8 fractures of the neck of the radius which had no primary displacement or had been ideally reduced showed no displacement at after-examination In 30 cases the displacement after treatment was slight 27 of these had no displacement at after-examination whereas the remaining 3 had not been totally

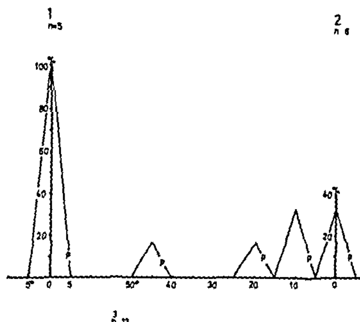


Figure 4

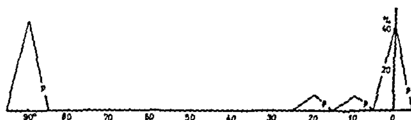


Figure 5

Figures 4–5 Difference in pronation between injured and uninjured arms in severely displaced fractures of the neck of the radius 1) No displacement 2) slight displacement 3) severe displacement after reduction + indicates that pronation was greater and — that it was smaller on the injured side

rebuilt Out of the 12 fractures left in severely displaced position after treatment 5 showed no displacement 4 slight and 3 still severe displacement

In 3 cases there had developed a synostosis between radius and ulna All of these had been severely displaced primarily Osteoarthritis at after-examination was seen in the Roentgen pictures in 8 cases 5 in fractures of the neck and 3 in fractures of the head of the radius All

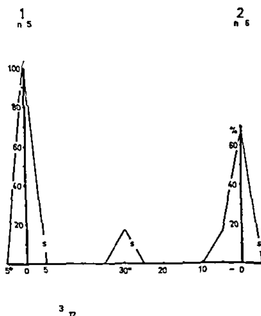


Figure 6

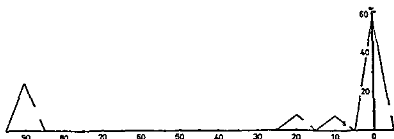


Figure 7

Figures 6–7 Difference in supination angle between injured and uninjured arms in severely displaced fractures of the neck of the radius 1) No displacement 2) slight displacement 3) severe displacement after reduction + indicates that supination was greater and — that it was smaller in the injured arm

of the fractures of the neck had been severely displaced primarily and no one had been properly reduced

The results were evaluated in the following manner Criteria for the result to be judged as good are Difference in carrying angle and/or limited flexion extension pronation supination ± 15–20 and/ or

Table 2 Working capacity in relation to type of fracture primary displacement an[d] result of reduction

Site of fracture	Neck of radius 50						Head of radius 5	T[otal]
Primary displacement	No 2	Slight 25		Severe 23			Slight 5	
After reduction	No 2	No 1	Slight 24	No 5	Slight 6	Severe 12	Slight 5	
Light work, without sympt	2	1	15	3	3	3	4	2
Light work, mild sympt.			2		1	4		
Light work, severe sympt.						2		
Heavy work without sympt			5	2	2	2		1
Heavy work mild sympt			2			1	1	

Table 3 Distribution of end results according to type of fracture primary displacement and result of reduction

Site of fracture	Neck of radius 50						Head of radius 5	Tot[al] 55
Primary displacement	No 2	Slight 25		Severe 23			Slight 5	55
After reduction	No 2	No 1	Slight 24	No 5	Slight 6	Severe 1[illegible]	Slight 5	55
Excellent	2	1	19	5	3	3	3	36
Good			5			4	2	11
Poor					3	5		8

mild symptoms during work If the result was better it was judged as "excellent and if it was worse it was judged as "poor

According to these criteria, 36 cases had excellent result 11 good

Table 4 Position of fragments primarily after treatment and at after examination

	Fractures of the neck of the radius			Fractures of the head of the radius	
Displacement	no	slight	severe	no	slight
Primarily	2	25	23	0	5
	2	1 5 24	6 12		5
After treatment	8	30	12	0	5
	8	27 5 3	4 3		5
At after examination	40	7	3	5	0

and 8 had poor result Their distribution among various types of displacement and the results of reduction are given in Table 3

DISCUSSION

It has been shown above that cubitus valgus in both elbows is significantly more common in subjects who have had a fracture in the neck or the head of the radius than in healthy subjects and people who have had other types of elbow fracture This seems to depend on that when a strain is put on the hand the elbow extended the pressure between the head of the radius and the capitellum of the humerus will increase with sinus of the supplement angle of the measured angle of valgus The mean supplement angles are thus 21 in the patient with fractures of the head or neck of the radius and 18 in all other types of elbows broken or not According to this the force in the radial part of the elbow is 12 per cent greater in the former group than in the second one with the same kind of trauma fall against the outstretched hand As dislocations and fractures of the ulnar epicondyle of the humerus

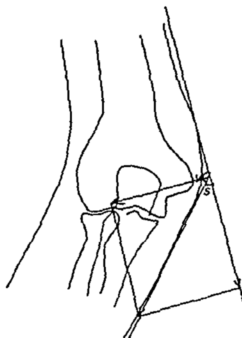


Figure 8 Showing the force in stopping a fall on the outstretched hand and the dividing of the force into two components the magnitude of which are proportional to sinus of the supplementary angle (s) of the measured angle of valgus (v)

In fractures of the neck and head of the radius $v = 159$ $s = 21$ $\sin s = 0.358$
In other elbows $v = 162$ $s = 18$ $\sin s = 0.309$

have been excluded from this group the pulling force in the ulnar part of the elbow has not been overcome See Figure 8

Although the patients in this group start with a cubitus valgus that is more pronounced than in other types of elbow injuries or in healthy subjects only 2 cases showed an increased valgus in the injured arm of more than 10 as compared to the healthy one The displacement after reduction was slight in one case and in the other the head of the radius was removed several years after the accident The support to the capitelium of the humerus thus seems to be only part of the stabilising structures in the elbow In one case treated by excision of the head of the radius primarily there was no difference in carrying angle between the healthy and the injured arms

Impairment of flexion and extension is uncommon and in this series does not exceed 20

Impairment of pronation and/or supination on the other hand is common in fractures of the head and neck of the radius and is the most

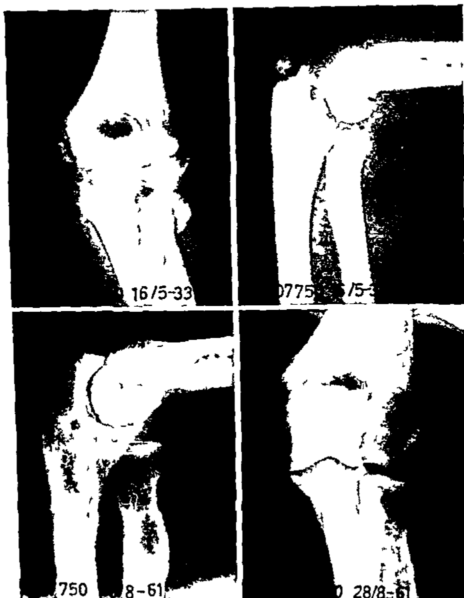


Figure 9 Fracture of the neck of the radius in a girl aged 10 Although there was a significant displacement the treatment was only immobilisation in a cardbord splint without reduction At after examination 28 years after the accident the patients has no complaints and no limitation in movements of flexion extension pronation or supination as compared to the healthy arm The strength in the arms and hands are equal Cubitus valgus was increased by 5 n the injured arm.

disabling factor All of the cases with severely impaired rotation movements had had fractures with severe displacement which had not been properly reduced or had been subject to excision of the head of the radius with a complete synostosis between radius and ulna

Although the series is so small that there is no statistical significance in the figures there can be no doubt that the chances for full mobility are better if the reduction has been exact

Excision of the fragment includes a great risk of synostosis between radius and ulna and is thus dangerous

Many authors (*Blount* 1954, *Ehalt* 1961 *Judet et al* 1962 *Keon Cohen* 1966) warn against excision of the head of the radius in children as the result is often a cubitus valgus Furthermore there is a risk of synostosis which can be even more disabling

The reduction is difficult As can be seen from Table 1 only 5 out of 23 severely displaced fractures were exactly reduced Closed reduction was successful in 4 cases out of 11, open in 1 case out of 5 The problem of retaining the fragment has been solved by *Judet et al* by transfixation with a Kirschner wire This incurs a risk of stopping the epiphyseal growth *Weller* (1965) denies this and proves experimentally that the wire can be left in the epiphysis which continues to grow

As compared to the frequency of osteoarthritis in supracondylar fractures of the humerus 2 per cent according to *Henrikson* (1966) the frequency is very high in this series There is also a marked difference in *this respect between the fractures of the neck and the fractures of the* head of the radius In the fractures of the neck the risk increases with the primary displacement and the displacement after reduction whereas the fractures of the head lead to osteoarthritis in 3 out of 5 cases although the displacement was not severe in any of these cases

The reason seems to be that the fracture line with callus formation is apt to interfere more with the joint when it is crossing the supporting joint surface The head of the radius makes two kinds of movement a flexion extension movement and a rotational one which may increase the development of osteoarthritis as the surfaces are more movable against each other than in the ulnar part of the joint

SUMMARY

Of 1579 subjects who had during childhood had elbow injuries which had been treated at the Children s Hospital Gothenburg during the

period 1930–50 1071 were after examinated in 1961–62 Of these 6 per cent had fracture of the proximal end of the radius and of these 55 have been the material for this article

Incidence 0 07 fractures annually per 1000 children 0–15 years of age The mean age was 9 7 years the sex distribution 28 boys/27 girls Cubitus valgus is more common both in the healthy and the injured arms in these cases than in other patients with elbow fractures or healthy subjects The end results were classified as excellent in 36 (65 per cent) as good in 11 (20 per cent) and as poor in 8 cases (15 per cent) The excellent results emanated mostly from fractures with no or slight primary displacement or such fractures which had been properly reduced but also some fractures with remaining displacement The poor cases emanated from fractures with severe primary displacement which had not been properly reduced

Deformity is not so common after these fractures as one could expect as the ulnar collateral ligament prevents the arm from slipping into valgus Flexion and extension is not commonly impaired Pronation and supination are impaired by remaining displacement and also by excision of the head of the radius which may lead to synostosis

The fractures in the proximal end of the radius although not common in children are important in that they not seldom give poor results especially depending on restricted pronation and supination This impairment of movement may be prevented in some cases by adequate reduction

REFERENCES

Arner O Ekengren K & von Schreeb T (1956) Fractures of the Head and Neck of the Radius *Acta chir scand* 112 115–134

Azzini C & de Iure T (1964) La nostra esperienza sul trattamento della frattura isolata del capitello radiale *Chir delgi org movimenti* LIII 273–287

Blount W P (1954) *Fractures in Children* Baltimore Williams & Wilkins Co

Campbell W (1929) Malunited Fractures and unreduced Dislocations about the Elbow *J.A.M A* 92 122

Carstam N (1950) Operative Treatment of Fracture of the Head and Neck of the Radius *Acta orthop scand* 19 502–526

Cave E (1958) *Fractures and other Injuries* The Year Book Publishers Inc Chicago

The Committee on Trauma (1949) *An outline of the Treatment of Fractures* American Collage of Surgeons Chicago

Door S J D (1964) Behandelingsresultaten van fracturen van het capitulum radii *Nederlands tijdschrift voor geneeskunde* 108, * 16 9–1664

Dougherty W (1966) Elbow Injuries in Children *Iowa M d Soc* 56, 1125–1132

Ehalt, W (1961) *Verletzungen bei Kindern und Jugendlichen* Ferdinand Enke Verlag Stuttgart

Hamon G Ducloux M & Carlier Cl (1963-1964) Fractures de la tete radiale *Lille chir* 18–19 125–135

Henrikson B (1966) Supracondylar Fracture of the Humerus in Children *Acta chir scand* Suppl 369

Judet J Judet R & Lefranc J (1962) Fracture du col radial chez l enfant *Annales de Chir* 16 1377–1385

Keon Cohen B T (1966) Fractures at the Elbow *J Bone Jt Surg* 48 A 1623–1639

MacLennan A (1937) Common Fractures about the Elbow Joint in Children *Surg Gynec Obstet* 64 447–453

Lorthioir J (1965) Traitement des fractures chez l enfant *Acta orthop belg* 31 611–618

Monaco L Venturoli W & d Amora T (1964) Contributo clinico statistico alla cura delle fratture del capitello radiale *Riv Infort Mal Prof* 51 117–136

Murray R (1940) Fractures of the Head and Neck of the Radius *Brit J Surg* 28 106–118

Patterson R F (1934) Treatment of Displaced Transverse Fractures of the Neck of the Radius in Children *J Bone Jt Surg* 16 695

Quigley & Banks (1960) *Progress in the Treatment of Fracturees and Dislocations 1950–1960* W B Saunders Co Philadelphia & London

Radin E L & Riseborough E J (1966) Fractures of the Radial Head *J Bone Jt Surg* 48 A 1055–1064

Reidy J & van Gorder G (1963) Treatment of Displacement of the Proximal Radial Epiphysis *J Bone Jt Surg* 45 A 1355 1372

Svinukhov N P (1965) The Outcomes of Operative Treatment of Fractures of the Neck of the Radius in Children *Ortopedija traumatologi i prote irovanie* 26 1 13–19

Weller S (1965) Zur Therapie kindlicher Gelenkbruche *Arch Klin Chir* 313 540–543

Wilson P (1933) Fractures and Dislocation in the Region of the Elbow *Surg Gynec Obstet* 53 335

Acta orthop Scandinav 40 261–272 1969

From the Department of Human Anatomy University of Gothenburg

TENSILE STRENGTH PROPERTIES OF ACHILLES TENDON SYSTEMS IN TRAINED AND UNTRAINED RABBITS

By

A Viidik

Received 22 ii 68

Tendons consist of parallel fibred dense connective tissue that is extensible and of great tensile strength properties investigated by numerous authors since *Wertheim* 1847 Its tensile strength has been estimated at 50 to 100 newton (N) per mm² (cf *Viidik* 1966) The stress strain curve commences with a toe part that is convex towards the strain axis (*e g Reuterwall* 1921 *Stucke* 1950 *Morgan* 1960) and considered to be caused by stretching the wavy formation of the collagenous bundles seen in a relaxed preparation (*Reutervall* 1921 *Rigby et al* 1959) The next part of the curve is fairly linear The failure may occur in this part of the curve or the curve may level off somewhat towards the stress axis before failure occurs (*Viidik et al* 1965)

The metabolic activity in such tissue is very slow once the latter is mature (*Neuberger & Slack* 1953 *Thompson & Ballou* 1956) In young animals however it responds at least morphologically to altered functional conditions *Ingelmark* (1945) trained growing rabbits in a treadmill and found that the cross sectional areas of the primary bundles in their Achilles tendons increased more than the number of cells In studies on white mice *Ingelmark* (1948) found that training enlarged the Achilles tendons in young animals but only the corresponding muscles in mature animals Thickening of a tendon does not necessarily mean improved performance of the whole functional bone tendon muscle tendon bone system as a healthy tendon is considered hardly ever to fail When such a functional system is subjected to increasing stress failure occurs most often as a tear off fracture at the insertion of the tendon into the bone (*McMaster* 1933 *Stucke* 1950

Davidsson 1954 1956) Other failure sites have also been reported *McMaster* (1933) described the musculo tendinous junction and the muscle belly to be other possible sites and *Finl & Wyss* (1942) re ported consistent failures in the muscle belly in the middle or near the musculo tendinous junction

Therefore to achieve maximum information on the mechanical behavior of tendons it is necessary to test (1) the complete system to ascertain the properties of the tendon until failure point of the weakest component of the system and discover which one it is and (2) the isolated tendon itself to evaluate its properties until failure of the collagen fibres themselves

This paper reports a series of rabbits trained in a running machine together with control rabbits of the same stock together with results on tensile strength testing of their complete Achilles tendon systems *i e* calcaneus Achilles tendon gastrocnemius muscle and femur The results of tensile strength tests of isolated hind limb tendons and of tensile strength and elasticity experiments on anterior cruciate liga ment preparations from knee joints of the same series of animals will be the subjects of future papers

MATERIALS AND METHODS

Fifteen male white rabbits about three months old and of the same stock trained in a running machine three times daily every week day for forty weeks (normally 5 days a week) The speed and running time were adjusted to the maximum capacity of the rabbits The scheme is shown in Figure 1 where the upper curve (ordinate A) gives the speed in meters per minute and the lower curve (ordinate B) gives the running time on each training occasion During the total training period they covered a distance of about 100 kilometers At the same time thirteen rabbits of the same stock were kept as controls and permitted to move about freely in standard cages (floor 69 × 45 cm) of the same type as those used for the trained animals The weights of the animals were checked weekly (Figure 2) The control animals tended to gain slightly more in weight than the trained ones but the difference was not statistically significant

An earlier group consisting of four similar rabbits trained in the same way and four control rabbits showed no statistically significant difference in weight gain compared with the main group It was therefore included in the material presented in this study after a confirmative analysis of variance of the results of the mechani cal testing in both groups

At the beginning of the training period the rabbits were immature but at the time of the mechanical testing their hind limbs were mature The criterion of maturity was cessation of skeletal growth as indicated by calcified epiphyseal plates This was checked in roentgenograms of the knee joints An immature animal is shown in Figure 3 and the same animal but after having reached maturity in Figure 4



Figure 1 The training scheme The upper curve (ordinate A) shows the running speed in meters per minute and the lower curve (ordinate B) the time in minutes of each running period (three times a day every week day)

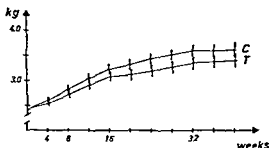


Figure 2 The weight of the trained (T) and control (C) animals during the training weeks (Mean values ± standard errors)

Preliminary studies showed that the tensile strength of the muscle tissue varied with the intensity of training before sacrifice and the interval between death and the test. If training had been intense or if a few hours had elapsed between death and testing the bone tendon muscle tendon bone system quite often failed in the mus le belly at rather lower loads To avoid these drawbacks the following method was employed and then true muscle rupture never occurred The animal was anaesthe tised with an intravenous injection of allypropymalum (5 mg per kg body weight) whereafter asphyxia was induced with an injection of tubocurarine (1 mg per kg body weight i v) The mechanical tests were performed within less than an hour of death

The system consisting of calcaneus Achilles tendon gastrocnemius muscle and femur was dissected out after the distal tendon of the peroneal and t bialis posterior muscles had been removed from the limb Care was t ken to keep the knee joint intact The calcaneus wa fre d f om other structu es than he Achilles tendon and fitted into a contour haped clamp with a rounded outlet for the tendon. A thin layer of polyethylene was placed between the metal of the clamp and the bone to improve the fit and t m the distribution of the holding forces more even The femur was also f tened into a contour shaped clamp without sharp edges where only the anterior and posterior ed es of the femoral condyles and a sl o t len th



Figure 3 Roentgenogram of the right knee joint of an immature animal at the start of the training period



Figure 4 Roentgenogram of the same knee joint as in Figure 3 but seven months later when the epiphyseal plates have calcified

of the femoral shaft were required for fixation with the muscle passing out bet een the two fixation sites Care was taken to avoid cutting the muscle when dissecting it free from surrounding tissues The soleus part of the triceps muscle was cut loose from its attachment The loose connective tissue covering the Achilles tendon was removed to enable a more accurate estimation of the site of the musculo tendinous junction and to prevent slipping of the registration marker

The clamp with the calcaneus was fastened to the immobile end of a material testing machine and the clamp with the femur was fastened to the piston that was operated by a hydraulic system regulated by valves and powered by an electric motor The load was registered continuously by a tensile force pick up (Philips PR 922C/02 max force 2000 N) As the elongation of the tendon and not of the whole system was of interest a marker was fastened at the musculo tendinous junction

The marker of stainless steel consisted of a ring with four bars in notches and at right angles to each other movable towards the center of the ring and fixable with screws The blunt ends pointing towards the center had rough surfaces and they were pressed against the tendon to hold it firmly without damage A flexible steel blade with a considerably stiffer U shaped end was placed against this ring thus causing the blade to bend in proportion to the tendon s elongation (cf Figure 5) The behavior of the musculo tendinous junction the marker and the U shaped blade were checked with cinematography in the preliminary experiments No slipping or oblique movements were noticed in analysis of the pictures both sequentially and individually The set up is shown schematically in Figure 5 The force is applied to the femur (A) and transmitted via the gastrocnemius muscle (B) to the tendon (D) The calcaneus (E) is fastened to the immobile end of the apparatus via the

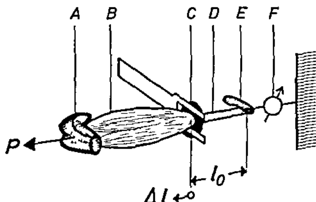


Figure 5 Schematic drawing of the mechanical experiment Force (P) is applied to the femur (A) and transmitted via the gastocnemius muscle (B) to the Achilles tendon (D) and resisted by the calcaneus (E) at the immobile end of the set up where force is recorded by a pick up (F) The deformation of the specimen from the immobile end Δl i e that of the tendon is recorded with a ring at the musculo tendinous junction (C) and a steel blade with a U shaped end

force pick up (F) The elongation of the tendon Δl is registered by bending of the steel blade with the U shaped end caused by the ring (C) at the musculo tendinous junction This bending was registered with strain gauges (Philips PR 9810) cemented on the blade and coupled in a half bridge Both the force pick up and the strain gauges were coupled to direct reading measuring bridges (Philips PT 1200) the strain gauges via a zero adjustment and switching equipment (Philips PT 1210) The elongation was performed at an almost constant speed, which was the same for all experiments The signals from the two bridges were recorded continuously by (1) a Siemens Oscillomink jet ink recorder with load and deformation on separate channels and (2) a Tectronix 502 oscilloscope that was x y-coupled and the tracing was photographed

Both load and deformation measuring systems were calibrated each day before and after the series of experiments The readings were found to be directly propor tional to load and deformation respectively in the measuring range used The error of measurement calculated as the coefficient of variation from multiple measure ments of known forces and deformations respectively was found to be 0 55 and 0 90 per cent

Mathematical and Statistical Methods

The oscilloscope photographs were subjected to cursory inspection and the follow ing parameters were analysed (cf Figure 6)

(1) tan α the coefficient of inclination of the linear portion of the load-deforma tion curve d stance A to B in Figure 6 corresponding to the elastic stiffnes of the tissue

(2) W_f the failure energy measured as the area between the curve and the de

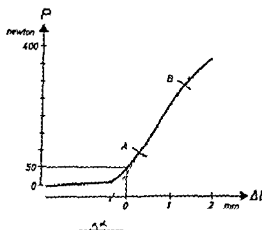


Figure 6 *Schematic drawing of an oscilloscope photograph from a tensile strength experiment on an Achilles tendon system The elongation is on the abscissa and the deformation on the ordinate For explanation see mathematical methods p 5-6*

formation axis from the starting point to the point of maximum load (shaded area in Figure 6)

(3) P_{max} the maximum load

(4) $\Delta l_{P_{max}}$ *the elongation at the maximum load point measured from the* point of elongation where the load was 50 N

(5) P_{lin} *the point at which the curve ends its linear portion and commences a* convexity towards the load axis (B in Figure 6)

The tan α and W_f values were calculated by a computer *The load and deformation* recordings from the Oscillomink were read for every millimeter changes in the load curve and the corresponding deformation values were read to the nearest quarter of a millimeter These data together with calibration data were processed by the computer First the mean tan α value for a whole group was estimated assuming that the linear parts of the load deformation curves should have a common starting point Then individual values were estimated by the method of least squares The standard error of the mean tan α for a group was estimated from all individual measuring points on the load deformation curves When calculating the failure energy values the load deformation curve was approximated to be linear between the points of measurement

RESULTS

The load deformation curves in both the trained and control groups started with a toe part concave towards the load axis Then a fairly linear portion ensued after which the curve tended to level off from the load axis until maximum load was reached After this point some of the curves levelled off an additional portion from the load axis before failure while others failed at once In both varieties failure could occur in one step or in several in rapid succession

Analysis of variance was performed for the two groups of animals No difference was found between the two trained and the two control groups The results in both series were therefore pooled

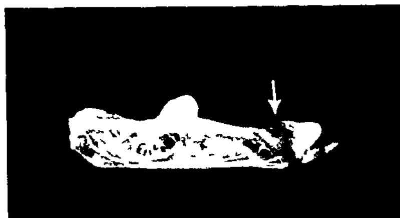


Figure 7 A roentgenogram of a calcaneus from a test specimen after the tensile strength test is completed and a tear off fracture has occurred (see arrow)

Table 1 Tensile strength parameters on the complete functional system of calcaneus Achilles tendon gastrocnemius muscle and femur All values are from the Achilles tendon except P_{max} which is for the weakest point in the whole system Mean values ± standard errors are given N = newton is the force unit in the International System of Units and 1 N = 0.102 kiloponds = 7.23 poundals

Parameter	Denomination	Trained	Controls
n	–	37	33
tan α	N/mm	176.8 ± 12.3	156.7 ± 10.1
W_f	Nmm	577.0 ± 46.6	552.1 ± 37.8
P_{max}	N	388.2 ± 19.8	377.4 ± 17.5
$\Delta l_{P_{max}}$	mm	2.42 ± 0.12	2.43 ± 0.11
P_{lin}	N	295.7 ± 16.9	285.3 ± 18.6

The results of computer analysis are given in Table 1 The tan α tended to increase with training but the increase was not statistically significant at the 5 per cent level (2P = 0.204) The W_f and P_{max} values showed a very slight increase in the mean values For all parameters the variation within groups was considerable

Parameter calculation was also performed with the deformation values reduced to units of original length measured as the distance between the calcaneus clamp and the ring (cf Figure 5) The coefficients of variation of the different parameters were not reduced by this procedure To enable summation of different parameters their values were by classification normalized to a standard variable with the



Figure 8 Sagittal section through the insertion of the Achilles tendon into the calcaneus Note the thickness of the tendon and the cortical bone (Decalcified section hematoxylin eosin stained 32 × magnification)

mean value of zero and the standard deformation of unity so that four almost equally sized groups were obtained in the control group This classification was performed on the basis of the various mean values and standard deviations of the parameters for the control animals The distributions were compared by χ^2 test This showed that the trained group differed significantly from the control group The difference was however due to considerable scattering in the trained group and not to overweight of positive values

The sites of rupture of the test specimens were recorded In the trained group 34 specimens out of 37 failed as tear off fractures of the calcaneus Of the remaining specimens two failed at the muscle s attachment to the femur and in one the failure started by a tearing off of the lateral gastrocnemius belly s insertion into the calcaneus where after the specimen failed in the muscle Three of the specimens in the control group failed in the same way one failed at the muscle s short tendinous attachment to the femur and one as a tear off fracture of the femur The remaining 28 of the 33 specimens in the control group failed as calcaneal tear off fractures Such a fracture is shown roentgenographically in Figure 7

DISCUSSION

From a general biological point of view it is of great interest to know how the mechanical properties of collagenous tissue react to increased functional demands The morphological picture has been evaluated earlier and the tissue has been found to react to these demands when young but not when adult (*Ingelmark* 1945 1948) In this study rabbits were trained in a running machine during the middle and later part of their growth period and by the time of mechanical testing the bones of their hind limbs were mature The trained animals tended to be slightly lighter than the untrained ones As both groups were fed ad libitum this may have been due to a somewhat smaller body fat mass No studies were however performed to check this possibility

This study confirms the opinion of earlier investigators that the tendon is not the weakest point in a bone tendon muscle tendon bone system and shows that this fact is not changed by training the animal Here it was also found that the insertion of the Achilles tendon into the calcaneus is the weakest point of the system and that the strength of the system is not altered by training This finding is in agreement with those of earlier investigators who used living anaesthetised animals i e *Stucke* (1951) and *Davidsson* (1954 1956) On the other hand *McMaster* (1933) reported more diverse failure sites using animals sacrificed at some unstated previous time This is in agreement with the present author s experience from preliminary experiments

Much discussion has been devoted to ruptures of the human Achilles tendon their mechanism and etiology Numerous authors believe in a pre existing degeneration e g *Arner et al* (1959) *Schönbauer* (1964) *Viernstein & Galli* (1964) and much interest has been focused on a locus resistentii minoris due to vascular deficiency (*Schnorrenberg* 1962 *Minne* 1967) Attempts have been made to correlate the clinical picture with experimental work but there is as pointed out by *Frings* (1961) a profound difference in the results in that in the clinical cases the tendon fails about 5 centimeters proximal to the calcaneus while in experimental work the failure occurs as a tear-off fracture In the experimental animal some rather violent attempts have also been made to simulate the histological picture of clinical degeneration (*Borsay et al* 1951) When making comparisons we must bear in mind the obvious anatomical differences between human beings and animals the Achilles tendon of the rabbit is inserted into a rather small part of the dorso plantar section of the calcaneus (Figure 8) and furthermore

the shape of the calcaneus of the rabbit (Figure 7) is *proportionally* longer and narrower than that of a human and it has a rather thin layer of cortical bone, into which the tendon fibres are inserted

Information on the mechanical properties of the tendon itself in the range above the system s failure point cannot be evaluated this way It is therefore necessary to perform mechanical tests on isolated tendons to ascertain whether the mechanical properties of the tendon itself have been altered by training or not Such tests on the distal tendons of the tibialis posterior peroneus longus tertius and quartus muscles from the same animals will be the subject of future papers

SUMMARY

19 rabbits were trained in a running machine while 17 rabbits of the same stock served as controls At the end of the training period of 40 weeks the calcaneus Achilles tendon gastrocnemius muscle femur systems were tested regarding their tensile strength The shapes of the load deformation curves were inspected and the following parameters calculated for the tendon until failure at the system s weakest point (1) the slope of the linear portion of the load deformation curve (2) *the failure energy* (3) the *maximum load* (4) *the elongation* at the maximum load (5) the point of load where the linear part of the load deformation curve ends The failure site was also recorded

It was concluded that the slope tended to become steeper with training but that no other parameters were altered The failure site proved to be the insertion of the Achilles tendon into the calcaneus It was concluded that studies on the properties of isolated tendons were needed to ascertain whether tendons change their mechanical properties in response to training or not

RESUME

19 lapins ont eté entraines dans une machine a courir alors que 17 lapins de la meme souche ont éte gardes comme sujets de controle A la fin de la periode d entrainement qui fut de 40 semaines le système du calcaneum – tendon d Acille – muscle gastrocnemius – femur a été soumise a des tests de force de tension Les courbes de la déformation de la forme a la charge ont éte étudiées et les paramètres suivants ont eté calcules pour le tendon jusqu a rupture au point le plus faible du système 1) l inclinaison de la portion lineaire de la courbe de déformation a la charge 2) le manque d énergie 3) la charge maximum 4)

l élongation a la charge maximum 5) le point de charge ou la partie lineaire de la courbe de deformation a la charge se termine La localisation de la rupture a egalement ete notee

Il est conclu que l inclinaison devient plus raide a l entrainement mais qu aucun parametre n est autrement modifie L endroit de la rupture s est montre etre l insertion du tendon d Achille sur le calcaneum Il est conclu aussi que des etudes sur les proprietes de tendons isoles sont nécessaires pour etablir si les propriétés mecaniques des tendons se modifient en relation avec l entrainement ou non

ZUSAMMENFASSUNG

19 Kaninchen wurden in einer Laufmaschine trainiert wahrend 17 Kaninchen desselben Stammes als Kontrollen behalten wurden Am Ende der Trainungs Zeit von 40 Wochen wurde das Calcaneus Achilles sehne Gastrocnemius Muskel Femursystem einer Probe auf Dehnbar keitsstarke unterworfen Die Form der Belastungsdeformierungskurven wurden besichtigt und die folgenden Parameter fur die Sehne bis zum Versagen am schwachesten Punkt des Systemes errechnet (1) Die Neigung des linearen Teiles der Belastungsdeformierungskurve (2) die Versagungsenergie (3) die maximale Belastung (4) die Verlangerung der maximalen Belastung (5) der Punkt der Belastung wo der lineare Teil der Belastungsdeformierungskurve endet Die Stelle des Versagens wurde ebenfalls aufgezeichnet

Die Schlussfolgerung war dass der Abfall der Kurve beim Trainieren die Neigung hatte steiler zu sein dass aber kein anderer Parameter verändert war Es erwies sich dass der Sitz des Versagens die Insertion der Achillessehne in den Calcaneus war Es wurde geschlossen dass Untersuchungen der Eigenschaften isolierter Sehnen notwendig waren um festzustellen ob Sehnen ihre mechanischen Eigenschaften als eine Trainungsreaktion verandern oder nicht

ACKNOWLEDGEMENT

Computer analysis programmed and statistical analysis supervised by *E Carlstrom* Ph D

REFERENCES

Arner O Lindholm A & Orell, S R. (1958/59) Histologic changes in sub utaneous rupture of the Achilles tendon. *Acta chir scand* 116 484–490

Borsay J Csipak, J & Dettre G (1951) Experimentelle Untersuchungen uber den Pathomechanismus der spontanen Sehnenruptur *Z Orthop* 81 55?–561

Davidsson L (1954) Tensile strength rupture and regeneration of tendons. *Ann Chir Gynaec Fenn* 43 61–65

Davidsson L. (1956) Über die subkutanen Sehnenrupturen und die Regeneration der Sehne *Ann Chir Gynaec Fenn* Suppl 6

Fink R & *Wyss O A M* (1949) *Experimentelle Untersuchungen uber Rupturen am Knochen Sehnen Muskel System beim Frosch* *Mschr Unfallheilk* 49 379–389

Frings H (1961) Über 88 subkutane Achillessehnenrupturen beim Sport *Mschr Unfallheilk* 64 325–329

Ingelmark B E (1945) Über den Bau der Sehnen wahrend verschiedener Altersperioden und unter verschiedenen funktionellen Bedingungen Uppsala Läk. *Foren Forh N F* 50 357–396

Ingelmark B E (1948) Der Bau der Sehnen wahrend verschiedener Altersperioden und unter wechselnden funktionellen Bedingungen I Eine quantitative morphologische Untersuchung an den Achillessehnen weisser Ratten *Acta Anat* (Basel) 6 113–140

McMaster P E (*1933*) *Tendon and muscle ruptures* *J Bone Jt Surg* 15 705–722

Minne J Depreux R Dorp J & Mauppin J M (1967) Les pédicules artériels du Tendon d'Achille *Bull Ass Anat Nancy* 136 699–706

Morgan F R. (1960) The mechanical properties of collagen fibres stress strain curves *J Soc Leath Trades Chem* 44 170–182

Neuberger A & *Slack H G B* (*1953*) *The metabolism of collagen* from liver bone skin and tendon in the normal rat *Biochem J* 53 47–52

Reuterwall O P son (1921) Über die Elasticitat der Gefasswande und die Methoden ihrer naheren Prüfung *Acta med scand* Suppl 2

Rigby B J Hirai N Spikes J D & Eyring H (1959/60) The mechanical properties of rat tail *tendon J gen Physiol* 43 265–283

Schnorrenberg G (1962) Über die Gefassversorgung der Achillessehne *Gegenbaurs morph Jb* 103 428–456

Schonbauer H R (1964) Gedeckte Achillessehnenrisse *Wiederherstellungschir u Traum* 8 160–185

Stucke K (1950) Über das elastische Verhalten der Achillessehne *im Belastungsversuch Langenbecks Arch klin Chir* 265 579–599

Stucke K (1951) Sehnenbelastung und ruptur im Tierversuch *Chirurg* 22 16–18.

Thompson R C & Ballou J E. (1956) Studies of metabolic turnover with tritium as a tracer V The predominantly non dynamic state of body constituents *in the rat J biol Chem* 223 795–809

Viernstein K & Galli H (1964) Achillessehnenrupturen *Wiederherstellungschir u Traum 8* 186–219

Viidik A (1966) Biomechanics and functional adaption of tendons and joint ligaments In F G Evans (ed) Studies on the anatomy and *function of bone and joints Springer Berlin pp* 17–39

Viidik A Sandqvist L & Magi M (1965) Influence of postmortal storage on tensile strength characteristics and histology of rabbit ligaments *Acta orthop scand* Suppl 79

Wertheim M G (1947) Mémoirs sur l'élasticité et la cohésion des principaux tissus du corps humain *Ann Chim Phys 3e Série* 21 385–414

Acta orthop Scandinav 40 273-278 1969

From the Department of Medical Physics (Head Professor A Engstrom) and the Orthopaedic Clinic (Head Professor S Friberg) Karolinska Institutet Stockholm Sweden

ON THE DISTRIBUTION OF MINERAL SALT IN AUTOGENOUS BONE GRAFTS IN MAN

Ulf Nilsonne

Received 26 i 68

In spite of the extensive literature on bone grafts—a bibliography by *Chase & Herndon* lists 855 papers published up to 1955—and the intensive research conducted in the past decade the central question of how osteogenesis is induced by a graft still remains to be answered The majority of the investigations reported have comprised animal experiments and one must be cautious about drawing analogies between these and clinical situations

In clinical work the incorporation of a bone graft is generally followed with conventional roentgenography which gives only a rough anatomical picture of the extent of mineralization This makes it desirable to obtain a picture of the microscopic distribution of bone salts in the graft The pattern of mineralization can be followed both quantitatively and qualitatively with microradiography which has been developed by *Engstrom* (1949) in particular *Holmstrand* (1957) and others have used this and complementary biophysical techniques in detailed studies of mineralization in experimental bone grafts Very few microradiographic papers have been published however concerning the effect of bone grafting in man The present paper is concerned with such cases obtained and investigated in connection with operative treatment of pseudarthrosis

MATERIAL AND METHODS

The clinical material comprised a total of 11 pseudarthroses on the ulna or radius Resection of the pseudarthrosis was undertaken in 9 of these cases the length of the resultant defect ranging from 1 8 to 3 5 cm The defect was filled with an autogenous



Figure 1 A Non union of the forearm 8 months after injury B Radical resection and internal fixation has been performed the defects in the bones have been filled by cancellous bone blocks from the iliac crest C Metallic fixation has been removed 10 months after bone grafting

graft consisting of a block of spongy bone taken from the iliac crest Internal fixation was achieved with Lane's plate The clinical effect of this surgical treatment has been reported by *Hierton & Nilsonne* (1962) The surgical technique is illustrated in Figure 1

Bone samples were obtained from the region of the graft when the material used for osteosynthesis was removed at different intervals after clinical healing had been noted Bone was obtained from 7 cases 10 19 months after the operation for pseudarthrosis Samples were taken from points corresponding to the middle of the graft and the boundary between this and the host bone The material was treated with the methods used by the author in microradiographic studies of fracture callus and pseudarthroses (*Nilsonne* 1959 1961)

RESULTS

Ten months after the operation (Figure 2) the graft displays islands with a relatively high degree of mineralization These areas lack structure and have a uniform appearance resembling necrosis Most of the osteoid tissue however displays a low degree of mineralization and there are numerous resorption zones The direction of the osteons varies and they seem to run both longitudinally and transversely Their mineralization is predominantly low

The picture is the same in principle in a specimen 15 months after



Figure 2 Longitudinal section from the middle of a graft 10 months after the transplantation



Figure 3 Longitudinal section from the transitional zone between the graft (to the left) and the host bone (to the right) 15 months after the transplantation

the transplantation (Figure 3) The homogeneous mature distribution of bone salts in the host bone is clearly distinguishable from the more varied picture in the graft with its lower average degree of mineralization The graft still displays necrotic looking islands with high mineralization and there are also several resorption cavities The Haversian systems are tending to become more organized

The principal features are still present in a specimen 19 months after the transplantation (Figure 4) There is however an increased reorganization of the graft region which is being transformed into something like mature bone There are only a few small necrotic remains of the original graft Mineralization is inhomogeneous but has increased somewhat in some Haversian systems compared with samples taken earlier The resorption cavities are more numerous and larger



Figure 5. Longitudinal section from the middle of a graft 19 months after the transplantation.

DISCUSSION

A study of the distribution of mineral salts in healed bone grafts cannot of course be used to show whether the graft has taken an active part in the process of repair or simply been passively incorporated in a callus region. The microradiographic investigation does, however, indicate the degree to which bone salts are deposited and the correlation between this and the various morphological structures in the graft region. This makes it possible to relate the progress of reorganization to the process of healing.

Stringa & Mignani (1967) and *Cauchoix et al.* (1966) seem to be the only authors who have so far reported microradiographic investigations on bone grafts in man. At the same time, neither of their materials is fully comparable with the present one. In the former case the graft consisted of cortical bone from the tibia, while in the latter the graft comprised both cortical and spongy bone and the operations were performed on growing individuals (fusion for scoliosis). In the present cases the graft consisted of spongy bone only and the operations were performed on fully grown individuals.

The remains of the original graft are a striking feature of the microradiographic pattern, still present more than a year after the transplantation as small, seemingly hypermineralized areas with a devitalized appearance. The same observations have been reported by *Cauchoix et al.* and *Stringa & Mignani*. The latter authors estimated that the density of the bone—measured as X-ray absorption—was about 10 per cent greater in the graft than in the callus bed. Clearly, resorption is a slow process even in the case of an autogeneous bone graft. There is no well

defined topographical line of resorption instead the process of mineralization corresponds to the histological pattern of creeping substitution

The invasion of the graft by osteoid tissue can be studied in the arrangement of the Haversian canals Even in late stages of healing osteons with a highly varied degree of mineralization are to be found running both longitudinally and transversely This suggests that vessels grow into the graft both from the host bone and from the surrounding soft tissues Microangiographic studies (*Gothman* 1961) have shown that the soft tissue reaction involves a lively formation of new vessels and the extension of vessels into the fracture callus It therefore seems that the entire graft region should be regarded as a callus region in clinical autogeneous bone grafts on the present scale Regardless of whether the graft does or does not develop an independent cellular activity it thus lies between the ends of the pseudarthrosis in a tissue that is probably analogous with that in fracture callus

As in the case of resorption the reorganization and remineralization of the graft takes a long time In this respect however there is a notable difference between the clinical development and the microscopic mineralization In the present cases full mechanical stability (*i e* clinical healing) was achieved within 3–7 months after the operation Complete consolidation was also obtained within this interval according to the macroscopic X ray examination The microscopic pattern however indicates that the graft is still undergoing reorganization 19 months after the operation numerous resorption zones as well as lamellar bone with a varying degree of mineralization There is thus a notable dissimilarity between clinical and biological healing of an autogeneous bone graft This agrees with observations from quantitative microradiography of experimental fracture callus (*Nilsonne* 1959) and experimental bone grafts (*Holmstrand* 1957)

SUMMARY

The distribution of mineral salts was investigated microradiographically in 7 cases of healed autogeneous bone grafts in man The pattern of mineralization is described and discussed with reference to the difference between clinical and biological healing

RESUME

La distribution de sels mineraux a été etudiee microradiographiquement dans sept cas de greffes autogenes osseuses consolidees chez l'homme

Une description generale de la mineralisation est donnee et discutée soulignant la difference entre consolidation clinique et biologique

ZUSAMMENFASSUNG

Die Verteilung von Mineralsalzen in geheilten autogenen Knochentransplantaten an 7 Patienten wurde mit Mikroradiographie untersucht Die Art der Mineralisation und besonders die Unterschied zwischen klinischer und biologischer Heilung wird besprochen

REFERENCES

Cauchoix J., Duriez J & Chosez J P (1966) L'arthrodèse vertébrale Remarques à propos de l'ostéogenèse de reparation *Rev Chir Orthop* 52 241

Chase S W & Herndom C. H. (1955) The fate of autogenous and homogenous bone grafts *J Bone Jt Surg* 37 A 809

Engstrom A (1949) Microradiography *Acta radiol* 31 503

Gothman L. (1961) Vascular reactions in experimental fractures *Acta chir scand* Suppl 284

Hiertonn T & Nilsonne U (1962) Ununited fractures of the forearm. *Acta orthop scand* 32 393

Holmstrand K. (195) Biophysical investigations of bone transplants and bone implants *Acta orthop scand* Suppl 26

Nilsonne U (1959) Biophysical investigations of the mineral phase in healing fractures *Acta orthop scand* Suppl 37

Nilsonne U (1961) The distribution of mineral salt in nonunion of fractures *Acta orthop scand* 31, 81

Stringa G & Mignani C (1967) Microradiographic investigation of bone grafts in man *Acta orthop scand* Suppl. 99

Acta orthop Scandinav 40 279–299 1969

From the Lab of Exp Biology Lab of Ultrastructure Research Dept of Anatomy
and Dept of Orthopaedic Surgery (Head Prof C. Hirsch M D)
University of Gothenburg Sweden

THE INFLUENCE OF SOME ANTI INFLAMMATORY DRUGS ON ORIGINAL AND REGENERATING SYNOVIAL TISSUE

P I BRÅNEMARK R EKHOLM I GOLDIE &
J LUNDSKOG

Received 25 xi 67

Among other tissues synovium is a target for the damaging effects of the still unknown initiating agent in rheumatoid arthritis At present the predominating view is that the changes seen in the synovial tissues in rheumatoid arthritis are of the nonspecific inflammatory type (*Kulka* 1959 1964 1966) Experimental work—including cold injury allergic phenomena and lesions obtained by vasospastic agents hyper tension and viral disease—has proved that the response of the mesen chymal tissues is one and the same irrespective of the eliciting agent (*Kulka* 1966) Similar conclusions were reached by *Branemark et al* (1967 a) when studying the effects of various inflammation producing agents on mesenchymal tissues

This response of the tissue is both vascular and cellular The vascular reaction appears to precede the cellular The former is characterized by venular dilation with secondary plasma leakage fibrinoid necrosis of the vessel wall and formation of thrombi Arteriolitis is occasionally noted Based on comparative light microscopic observations the general opinion is that an angiopathy dominates the picture (*Cruickshank* 1954 *Kulka* 1966 *Sokoloff* 1963) In a recent study we (*Branemark Ekholm Goldie* 1967) have however suggested that ultra structural vascular changes are minimal

As for the cellular behaviour there is a patchy infiltration of lympho cytes often around vessels There is a scarcity of neutrophils Fibrinoid

Supported by grants from the Swedish Med Res Council Swedish Antirheum League and King Gustav V s fund

necrosis in the connective tissue may be seen Besides the interstitial fibrin deposition a connective tissue proliferation is observed The cellular and intracellular reactions are believed to be secondary to increasing microcirculatory insufficiency (*Kulla* 1966)

It is conceivable that besides general therapeutic measures in rheumatoid arthritis there are also procedures acting more concentratedly on the local articular manifestations The aim is to reduce the inflammatory reaction This can be achieved by drugs or by surgery In the former case anti inflammatory substances as *e g* steroids and salicylates are commonly used The surgical management is directed either to the soft tissue as *e g* synovectomy, or to skeletal structures as *e g* arthroplasties or arthrodeses

Irrespective of method used the aim is to combat the pain—due to the inflammatory reaction—and malposition and stiffness of joints due to destruction of tissue In those cases where diseased synovial tissue is locally treated it is of importance to know what the reaction of the tissues lining the joint cavity may be to particular local treatment and its influence on the regenerating tissue after synovectomy

For this reason we have carried out an experimental study on animals to investigate the influence of some anti inflammatory drugs on normal synovial tissue and on its regeneration after synovectomy

MATERIAL AND METHODS

The substances used in this investigation were methyl prednisoloneacetate (Depomedrome®) prednisolone tertiary butyl acetate (Codelcortone TBA) and 0 2 per cent solution of salicylate They were injected at regular intervals in doses as described below into the knee joints of dogs and rabbits In all seventeen joints were thus injected and in another five the regeneration of synovial tissue after synovectomy was observed

Methylprednisoloneacetate (Depomedrone®) Four rabbit knee joints were partially synovectomized leaving the posterior area intact as described in an experimental study by *Lindstrom* (1963) On the day of synovectomy and following this at two day intervals the joints were injected with 1 5 ml Depomedrone on two occasions and 0 5 ml on three consecutive occasions A total of five injections was thus achieved The animals were allowed to run freely around without any immobilisation Daily checkings were made of joint mobility and postoperative reaction The experiment was terminated fourteen days after its initiation

Prednisolone tertiary butyl acetate (Codelcortone TBA) Four rabbit joints were synovectomized On the day of synovectomy and at subsequent two day intervals 1 ml prednisolone tertiary butyl acetate was injected totally five injections Postoperatively the rabbits were freely mobilized and the experiment was ended fourteen days after its initiation

0.2 per cent solution of salicylate. In this study rabbits and dogs were used.

Rabbits. Four knee joints were synovectomized and 1 ml 0.2 per cent buffered blood isotonic solution of salicylate was injected on the day of surgery. Following this the same amount was injected at two day intervals. Five injections were made. The rabbits ran freely around immediately postoperatively. The experiment was terminated after fourteen days.

Dogs. Five dog joints were injected at regular intervals with 0.2 per cent solution of salicylate without any previous synovectomy. The injected joints were freely mobilized. The injections were done at weekly intervals and altogether six injections were made. The experiment was terminated after two months with 2–4 weeks between the last injection and termination.

In all dogs who had solution of salicylate injected into one knee joint the opposite side was synovectomized at the initiation of the experiment. This was done 1) to study synovial regeneration in the dog 2) to observe if possibly the injected salicylate in the non-synovectomized side may by blood borne conveyance via the capsular bone marrow vessels in any way influence the regenerating synovial tissue.

At the termination of experiments tissues were taken for histologic and electron microscopic study. Haematoxylin-eosin and van Gieson stains were used. A control material consisting of synovial tissues from normal rabbits and dogs were technically processed in the same way.

A microangiographic study was also carried out. The aorta was dissected to the renal arteries and a catheter was introduced distally. To obtain an equilibrium of the intravascular fluid volume a perforation of the inferior caval vein was made distally. The vascular system was then perfused with a contrast solution of 25 per cent Micropaque in physiologic saline. Before the perfusion the animals were heparinized. The perfusion pressure was not measured but excessive pressures could be avoided as the injections were made by hand. In cases of increased resistance this was markedly decreased by intravenous injection of 5 ml 2 per cent Xylocain. The perfusion was interrupted when pure contrast filled the vena cava.

After angiography the specimens were immediately fixed in formalin and after two days all remaining muscles were removed. Following this the specimens were further fixed in 5 per cent neutral formalin with decalcification in formic acid. Finally the samples were embedded in paraffin. The specimens were cut in 800 microns thick pieces.

A Machlett OEG-50 tube was used for the microradiographic study. Exposures were made on Kodak MR plates with a distance of 15 cm at 17 kV 20 mA and 15 minutes.

Synovial tissue from the dogs were also subjected to electron microscopical examination. For this purpose small pieces of synovial tissue from various parts of the joints were excised and immediately immersed into a fixative consisting of 3 per cent glutaraldehyde buffered at pH 7.2 by sodium cacodylate. Two hours later the tissue pieces were transferred to a second fixative containing 1 per cent osmium tetroxide buffered at pH 7.2 with Veronal acetate. After postfixation for 1.5–2 hours the tissue was dehydrated in ethanol and embedded in Epon. The sectioning was performed on an LKB Ultrotome. The sections were stained with uranyl acetate and lead citrate and examined in a Siemens Elmiskop I.

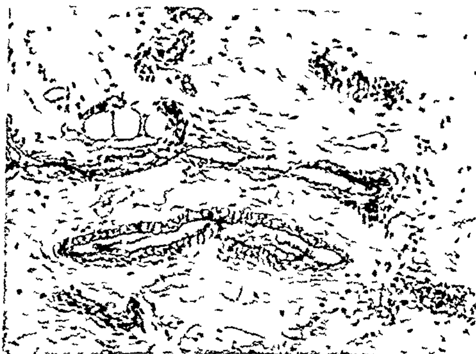


Figure 1. *Synovial tissue from rabbit's knee joint treated with methylprednisolone acetate. Quiescent tissue without signs of abnormal cellular or vascular reaction.* × *150.*

RESULTS

Methylprednisolone Acetate (Depomedrone®)

In the postoperative course no adverse effects were noted. The wounds healed without complications, no articular swelling was observed and motion was unimpaired.

On microscopic examination of the opened joint at the termination of the experiment the scar tissue in the incision after the previous synovectomy was completely without any pathologic signs. No ruptures, haemorrhages or granulomas were observed. The various layers could with ease be detached from each other. On opening of the joint the cartilage appeared normal, the bone cartilage zone was uninterfered with, the remaining synovium was glossy but not oedematous. There were no signs of retained steroid like microcrystals or suspension substance in the synovium or in the articular folds. The region where the synovectomy had been performed was normal and small granulation tufts of normal appearance were observed in the bone cartilage zone and along the inner side of the fibrous capsule which previously had

been lined by synovium There was no excess of joint fluid The cartilage was intact and on the whole no structural abnormalities were observed

Histology There was little reaction in vessels cellular compartment and intercellular substance The area of incision showed an increase in collagenous bundles and fibroblasts Signs of inflammation i e neutrophils infiltration of plasma cells increase in the number of vessels oedema and minor haemorrhage were not conspicuous (Figure 1) There were no areas of circumscribed necrosis of the fibrinoid type and the vessel walls all remained normal No thrombi were detected The granulation tufts in the bone cartilage zone were as expected rich in vessels and histiocytes which were diffusely scattered without any tendency to patchy infiltrations No foreign body reaction was seen and the general impression was that of a quiescent tissue of normal appearance Cartilage and bone were normal

Prednisolone Tertiary Butyl Acetate (Codelcortone TbA®)

This appeared very soon as quite a noxious substance Within three days following synovectomy the joints were distended with a swollen joint capsule The patella was in all cases dislocated laterally The animals refused to bear weight on the injected leg The wounds tended in all joints to rupture spontaneously on the fourth to sixth days there was discharge from the joints of thick fluid Sutures were dislodged On opening the joint in all animals it was found that the subcutaneous tissues had ruptures and that the skin was the only covering layer of the joint Large floccular greyish white masses were either lodged in the subcutaneous soft tissues or freely floating around in the synovial fluid This was excessive and of yellowish grey thick appearance though not purulent In two cases there were fistulas from the joint cavity ending blindly in the surrounding soft tissues The joints were all surrounded by thick oedematous tissues The cartilage of both femur and tibia were in all cases covered by a thin membrane which had a jelly like appearance The remaining synovial tissue was oedematous and intensely reddened It adhered in a gluey fashion to the osseous structures

Histology The macroscopic observations were not congruent to the microscopic findings The most striking feature was oedema Collagenous bundles and cellular components were split up by a patchy gelatinous substance which apparently did not create any peripheral vascular or cellular reaction Nevertheless areas were found with infil

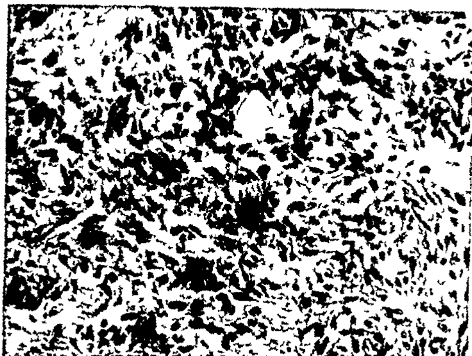


Figure 2 Synovial tissue from rabbit s knee joint treated with prednisolone tertiary butyl acetate Rich cellular invasion of plasma cells and some neutrophils There is some hypervasculari ation × 300

trations of plasma cells and neutrophils and in addition some thick walled vessels of both arteriolar venular and capillary type (Figure 2) No thromboses were observed The border zones of the ruptures were richly vascularized and penetrated by numerous mononuclear cells The cartilage and bone appeared normal On the whole the histologic appearance was fairly innocent and did not give the dynamic impres sion as did the macroscopic findings

0 2 per cent Solution of Salicylate

Rabbits Postoperatively all the joints were normal without effusions or other pathologic signs All animals moved their limbs forcibly and could bear weight without difficulty

Histology No abnormalities were encountered

Dogs The joints injected with solution of salicylate were *not* synovectomized prior to injection All joints appeared normal throughout the observation period of two months On macroscopic examination of the opened joints at the termination of the experiment all the extra



Figure 3 Synovial tissue from dog s knee joint treated with salicylate solution The tissue is in parts areolar without signs of abnormal reaction Some cellular clusters are observed but these also occur in normal non treated tissues × 200

articular soft tissue layers were intact The synovial tissue was slightly oedematous but otherwise without signs of inflammation There was no synovial effusion The cartilage appeared normal and the bone car tilage zone did not disclose any abnormalities In scattered areas the synovial tissues appeared more richly vascularized but the vascular ar chitecture was quite normal

Histology In all instances completely normal conditions were present (Figure 3)

Microangiography As is apparent from Figures 4 a and b the micro vascular architecture is normal The salicylate injections did not leave the impression of interfering with the quantity or quality of the vessels There was normal distribution and the arborisation did not signify any abnormal response to the injected agent

Electronmicroscopy Arterioles venules and capillaries of the synovial tissue were studied with the electron microscope It can be stated that these vessels in all respects displayed quite normal ultrastructural features

The *arterioles* (Figures 6 7) had inside an outer layer of collagenous bundles, one or two layers of smooth muscle cells each of which was enveloped in a basement membrane The muscle cell cytoplasm had the appearance well known from several earlier studies and characterized by a large number of peripherally localized small vesicles and bundles of myofilaments The muscle coat was separated from the endothelium by a media which in the larger vessels had a continuous layer of elastic tissue In the smaller vessels this tissue showed several discontinuities (Figure 6) The endothelial cells were of varying height but generally higher than those of the capillaries The luminal surface was irregular, displaying variously sized and shaped projections and a few slender villi The endothelial cells contained normal looking cytoplasmic components, the most characteristic of which are pinocytotic vesicles and bundles of 70 Å thick filaments (Figure 7)

The *capillaries* and *small venules* were apart from the calibre very similar (Figures 8 9 10) The endothelial cells had fundamentally the same structure as described above for the endothelium of the arterioles A difference was however that both in capillaries and small venules the endothelium was within large areas very thin, measuring only a few hundred Å (Figure 9) However a cytoplasmic lining did always exist and real pores and fenestrations covered by a thin membrane the latter of which exist in several tissues (1 2 3 4) were not found in the synovial tissue The cell junctions did not show any widenings or other changes The cytoplasmic components including those most characteristic of endothelial cells—vesicles and filaments—had a normal appearance (Figure 10) The peripheral surface of the endothelium was always covered by a continous basement membrane Outside this membrane there was according to the size of the vessel a varying amount of connective tissue elements in the form of collagenous fibrils and fibroblasts with long slender projections

---

Figure 4 A Microangiogram (transverse section through femoral condyle region) of dog s knee joint treated with salicylate solution Normal vascular architecture with vessels connecting marrow space with synovial tissue via bone substance Contrast has leaked out in marrow spaces which is due to a disruption of marrow veins during injection × 10

Figure 4 B Sectional enlargement of 4 A Vessels from the marrow open freely into the cartilage zone the peripheral limit of which is marked by white dotted line The vascular appearance is normal as to quantity and individual form and distribution

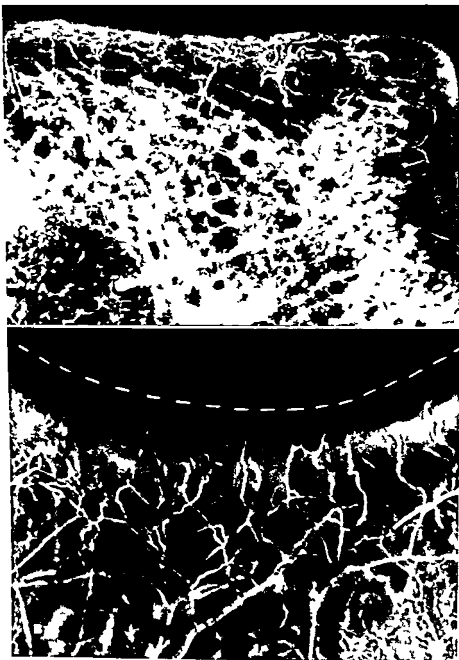


Figure 4

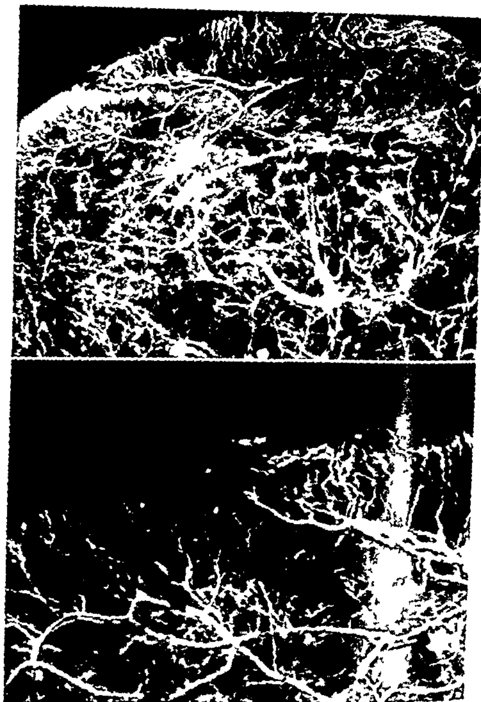


Figure 5A. Overall view of microangiogram (transverse section through femoral condyle region) from dog's knee joint 2 months after synovectomy. Marrow vessels branch out in rich vascular arborisation in bone cartilage zone where regeneration of synovium occurs. × 9



Figure 6 Survey electron micrograph of an arteriole in the synovial tissue from a joint subjected to salicylate injections The vessel is provided with a single layer of smooth muscle cells (SM) separated from the endothelium (E) by a media containing heavily stained elastic tissue Note the irregular course of the luminal surface of the endothelium Outside the muscle layer there are collagenous fibrils running in various directions —Magnification × 45 000

Figure 5 B Sectional magnification of region of hyperva ular ty n bone cartilage zone where synovium regenerates The microvasculature is normal for this type of regenerat ng t ssue × 4



Figure 7 Electron micrograph showing a detail of the endothelium of the arteriole in Figure 6 The endothelial cell cytoplasm contains a few mitochondria (M) a Golgi apparatus (G) endoplasmic reticulum with ribosomes (ER) numerous small vesicles some of which open at the cell surfaces and bundles of fine filaments (F) The arrow points at the junction of two cells To the left a portion of the media Magnification × [illegible]



Figure 8 Survey electron micrograph of a capillary in the synovial tissue from a salicylate treated joint The endothelium (E) is thinner than in the arteriole (cf Figure 2) Close to the outer surface of the endothelium there is a basement membrane (BM) and more peripherally several slender projections from fibroblasts (FB) are seen as well as bundles of collagenous fibrils — Magnification × 7,000

Regenerated Synovial Tissues in Dog Joints not Subjected to any Injections

In all the post-operative course was uncomplicated The joints could be freely moved without impairment or pain On macroscopic examination at termination of the experiment two months after synovectomy the zone of incision was quite reactionfree though the tissues were slightly thicker harder and more firm than the surrounding tissues There were no adhesions between the individual layers which were easily separated The synovial tissue had regenerated and appeared as a very thin glossy membrane without any obvious richness in vessels The tissue could easily be removed from the femoral condyles and excised as a sac No oedema was present No ruptures or other structural



Figure 9. Electron micrograph of a detail of the capillary in Figure 8. Over a long distance the endothelial cell (E) is very attenuated but there are no breaks in the capillary lining. Even the thin portions contain pinocytotic vesicles, a few ribosomes and filaments. The basement membrane (BM) forms a continuous layer along the endothelium. (C) denotes cross sectioned collagenous fibrils. Magnification × 39 000

abnormalities were observed. The cartilage appeared normal. Nothing abnormal was seen in the bone-cartilage zone. There was no increase in synovial fluid.

Histology. The microscopic examinations revealed normal synovial tissue. No structural aberrations were noted.

Microangiography. In Figures 5 a and b the vascular pattern is more lively and active indicating a response of repair type. The vessels are smooth but slightly tortuous, but the increase of vessels falls within the normal limits or vascular response to the activity of regenerating tissues.

DISCUSSION

The purpose of this study was to test some anti-inflammatory drugs commonly used in rheumatoid arthritis when administered locally in joints. The question of interest was to what extent these drugs may influence the morphologic structure of the present synovial tissue and if any interference of these could be noted in the regeneration of synovium after synovectomy.

The synovium regenerates within 90 days after synovectomy in normal animal joints (*Sumita* 1912, *Key* 1925, *Lindstrom* 1963). The regenerated tissue is considered to be structurally and functionally normal. In rheumatoid arthritis, it is claimed that after synovectomy

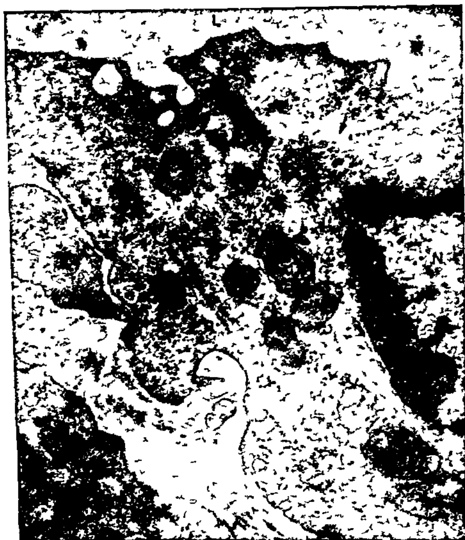


Figure 10 Electron micrograph of a detail of a capillary (salicylate treated joint) showing a thick portion about the cell nucleus (N) of an endothelial cell It is clear that there are no essential structural differences between this endothelial cell and that of the arteriole in Figure 7 M–mitochondrion ER–endoplasmic reticulum F–filaments L–capillary lumen —Magnification × 37 000

the regenerated synovial tissue also is normal *from a morphologic* point of view (*Preston* 1967 *Marmor* 1966) Certain observations made *by one of us* (*Goldie* 1967) *indicate however* that post synovectomy the regenerated tissue may retain a morphologic appearance similar to that of the original diseased synovium With that in mind it has been assumed that whatever anti inflammatory properties the drugs commonly used for local application in rheumatoid arthritis may have or which could be used in this application may on administration immediately after synovectomy subsequently influence the regenerating tissue to normal appearance and function

Before engaging on an investigation of this kind it is however essential *to establish the innoxiousness of the drugs employed*

We have already pointed out (*Brånemark, Goldie & Lindström* 1967 *Brånemark & Goldie* 1967) that certain steroid preparations contain components in the *suspension* vehicle which have a deleterious effect on the microcirculation in normal synovial tissues The retarding effect on healing tissues of steroids is also well known

As steroids are used for local therapy in rheumatoid arthritis it was thought of some interest to investigate their properties in joints with regenerating tissues of normal type If no adversities were encountered in this procedure it may well be possible to institute an injection therapy following synovectomy This is of particular interest as own observations (*Goldie* 1967) *indicate that the pathologic process appears to* accompany the regeneration

The results in *this investigation* disclose *that certain steroids* containing high molecular preservatives of the type sorbitol as does prednisolone tertiary butyl acetate cannot be used because of their tissue destroying properties Pure steroids do not however cause this damage and it is therefore desirable that they are suspended in vehicles which do not contain tissue destructive components The use of methylprednisolone acetate has in this investigation yielded no adverse effects This may therefore be a drug which could be tried as an anti inflammatory agent following synovectomy

The analgesic properties of salicylates are well known but little has been investigated on their anti inflammatory characteristics in local application *Fremont-Smith & Bayles* (1965) have come to the conclusion that the important action of salicylates is their inhibition of inflammation and secondary *to this* an analgesia ensues *Fearnley & Aaron* (1965) have used intra articular injections of 5 per cent benzyl salicylate in patients with osteoarthritis in the knee Moderate improve-

ment in the clinical condition was noted and no adverse effects of the locally applied salicylate were observed

As shown in this investigation salicylates do not appear to have any deleterious influence on normal regenerating animal synovial tissue either in an early stage or in the later development

Moreover it has been shown that human synovial tissues [illegible] react inadvertly to local application of salicylates (*Laernlay &* [illegible] 1965) The results of synovectomy as such are certainly [illegible] but could be improved and it remains desirable that the [illegible] tissue should be normal in structure and function after synovectomy As certain observations indicate that the regenerating synovial [illegible] holds some pathomorphologic characteristics of the inflammatory [illegible] (*Goldie* 1967) these might be combated by the use of anti inflam[illegible] drugs early in the postsynovectomy phase The local application of salicylates in this phase may therefore be justified

SUMMARY

Besides general therapeutic measures in rheumatoid arthritis [illegible] also includes procedures acting more concentratedly on the [illegible] ular manifestations This can be achieved by anti inflam[illegible] stances like steroids and salicylates

It is of importance to know what the reaction of the [illegible] the joint cavity may be to a particular local treatment [illegible] on the regenerating tissue after synovectomy Therefore [illegible] been carried out on the influence of anti inflammatory [illegible] synovial tissues

Methylprednisolone acetate (Depomedrone) pred[illegible] butyl acetate (Codelcortone TBA) and 0 2 per cent [illegible] used These were injected into the knee joints of [illegible]

The rabbit knee joints were synovectomized and [illegible] substances were injected at regular intervals

In the dogs one knee joint was injected with [illegible] out previous synovectomy The contralateral [illegible] without any injections being made

The results disclosed that rabbit knee joints [illegible] drone and salicylate solution showed no [illegible] Those injected with Codelcortone TBA show[illegible] ruptures of operating wounds and granula[illegible]

The dogs disclosed nothing abnormal

Registration of the results was made by ordinary histology micro-angiography and electron microscopy for particular study of the vessel walls which revealed no pathologic abnormalities

It has become apparent from this investigation that some drugs with anti inflammatory properties when locally applied on the whole are substances without obvious noxious effects on individual structural elements in original and regenerating synovial tissues Local application of these may serve as a therapeutic adjuvant in the postsynovectomy phase in certain patients in whom it appears that the pathologic process accompanies the regeneration of synovial tissues the pathologic function of which should be combated

RESUME

A cote de mesures therapeutiques générales le traitement de l arthrite rhumatoide peut aussi comprendre une action plus concentree sur les manifestations articulaires locales Cela peut etre realisé au moyen de substances anti inflammatoires telles que les steroides et les salicylates

Il est important de savoir quelle peut etre la reaction des tissus revetant la cavite articulaire a un traitement local particulier et son influence sur le tissu de régénération apres synovectomie C est pourquoi nous avons etudie l influence des medicaments anti inflammatoires sur le tissu synovial des animaux

L acetate de methylprednisolone (Depomedrone) l acétate butylique prednisolone tertiaire (Codelcortone TBA) et une solution de 0 2 pour cent de salicylates ont eté utilises Ils ont été injectes dans les articulations du genou de lapins et de chiens

Il a te procede a une synovestomie de l articulation du genous des lapins apres laquelle les substances furent injectées a intervalles reguliers

Dans les articulations du genou des chiens il fut injecté une solution de salicylates sans synovectomie prealable Une synovestomiee a ete pratiquee dans le cote contralateral sans faire d injections

Les résultats révèlent que les articulations du genou des lapins injectés avec Depomedrone et solution de salicylate ne presentent aucune anomalie pathologique Chez ceux injectes avec Codelcortone TBA on a constaté des alterations marquées avec rupture des plaies d opération et formations de tissu de granulation

Chez les chiens rien d anormal

L enregistrement de ces résultats a été fait par histologie ordinaire

microangiographie et microscopie electronique pour étude particulière des parois des vaisseaux qui n ont pas revele d anomalie pathologique Cette étude a fait ressortir que certains medicaments ayant des propriétés anti inflammatoires sont dans l ensemble lorsqu ils sont administres localement des substances sans effet nocif visible sur les elements structuraux individuels du tissu synovial original ou regenere Une application locale de ceux ci peut servir de therapeutique adjuvante dans la phase qui suit la synovectomie pour certains malades chez lesquels il apparait un processus pathologique qu il convient de combattre accompagnant la regeneration du tissu synovial

ZUSAMMENFASSUNG

Abgesehen von allgemeinen terapeutischen Massnahmen bei der chronischen rheumatischen Arthritis schliesst die Behandlung auch Verfahren ein die konzentrierter auf die örtlichen Gelenkserscheinungen wirken Dies kann mittels entzundungshemmender Stoffe wie Steroide und Salycilate erreicht werden

Es ist wichtig zu wissen welches die Reaktion der Gewebe die den Gelenksraum umgeben gegenuber einer besonderen lokalen Behandlung sein kann und ihren Einfluss auf regenerierendes Gewebe nach Synovektomie zu kennen Deshalb wurde eine Untersuchung über die Einwirkung von entzundungshemmenden Mitteln auf tierisches Synovialgewebe ausgefuhrt

Methylprednisolon Acetat (Depomedrone) Prednisolon tertiares Butyl Acetat (Codelcortone TBA) und 0 2 Prozent Salycilatlösung wurden verwendet Diese wurden in das Kniegelenk von Kaninchen und Hunden eingespritzt

Eine Synovektomie der Kaninchenkniegelenke wurde vorgenommen und nachher wurden diese Substanzen in regelmassigen Zwischenräumen injiziert

Bei den Hunden wurde ein Kniegelenk ohne vorhergehende Synovektomie mit der Salycilatlösung injiziert Die kontralaterale Seite wurde synovektomiert ohne dass man Einspritzungen vornahm

Die Resultate ergaben dass Kaninchengelenke die mit Depomedrone und Salycilatlösung injiziert worden waren keine pathologischen Anomalien aufwiesen Jene die mit Codelcortone TBA injiziert worden waren zeigten bedeutende Veränderungen mit Rupturen der Operationswunden und Bildung von Granulationsgewebe

Die Hunde wiesen keine Anomalien auf

Registration of the results was made by ordinary histology, microangiography and electron microscopy for particular study of the vessel walls which revealed no pathologic abnormalities

It has become apparent from this investigation that some drugs with anti inflammatory properties when locally applied on the whole are substances without obvious noxious effects on individual structural elements in original and regenerating synovial tissues Local application of these may serve as a therapeutic adjuvant in the postsynovectomy phase in certain patients in whom it appears that the pathologic process accompanies the regeneration of synovial tissues the pathologic function of which should be combated

RESUME

A cote de mesures therapeutiques generales le traitement de l arthrite rhumatoide peut aussi comprendre une action plus concentree sur les manifestations articulaires locales Cela peut etre realise au moyen de substances anti inflammatoires telles que les steroides et les salicylates

Il est important de savoir quelle peut etre la reaction des tissus revêtant la cavite articulaire a un traitement local particulier et son influence sur le tissu de regeneration apres synovectomie C est pourquoi nous avons etudie l influence des medicaments anti inflammatoires sur le tissu synovial des animaux

L actate de methylprednisolone (Depomedrone) l acetate butylique prednisolone tertiaire (Codelcortone TBA) et une solution de 0 2 pour cent de salicylates ont ete utilises Ils ont ete injectes dans les articulations du genou de lapins et de chiens

Il a te procede a une synovestomie de l articulation du genous des lapins apres laquelle les substances furent injectees à intervalles régu liers

Dans les articulations du genou des chiens il fut injecté une solution de salicylates sans synovectomie préalable Une synovestomiee a été pratiquee dans le cote contralateral sans faire d injections

Les résultats révelent que les articulations du genou des lapins injectés avec Depomedrone et solution de salicylate ne presentent aucune anomalie patholique Chez ceux injectés avec Codelcortone TBA on a constate des alterations marquees avec rupture des plaies d operation et formations de tissu de granulation

Chez les chiens rien d anormal

L enregistrement de ces resultats a été fait par histologie ordinaire

Key J A (19?5) The reformation of synovial membrane in the knees of rabbits after synovectomy *J Bone Jt Surg* 7 793

Kulka J P (1959) The pathogenesis of rheumatoid arthritis *J chron Dis* 10 388

Kulka J P (1964) Microcirculatory impairment as a factor in inflammatory tissue damage *Ann N Y Acad Sci* 116 1018

Kulka J P (1966) Vascular derangement in rheumatoid arthritis *Modern trends in rheumatology* Ed Alan Hill Butterworths

Lindbeck G Conger J Tippit D & Kelley V (1966) The effects of salicylates on growth in immature rats *Arthr Rheum* 9 776

Lindstrom J (1963) The microvascular anatomy of synovial tissue *Acta rheum scand* Suppl. 7

Marmor L. (1966) Synovectomy in rheumatoid arthritis *Clin Orthopaedics* 44 151

Monif G & Ragan C. (1962) The antiinflammatory effect of salicylates in poly myositis *Arthr Rheum* 5 513

Preston R. (1967) *Surgery in rheumatoid arthritis* Symposium on Early Synovec tomy in Rheumatoid Arthritis I S R.A Amsterdam 1967

Rhodin J A G (196?) The diaphragm of capillary endothelial fenestrations *J Ultrastructure Res* 6 171

Sokoloff L. (1963) The pathophysiology of peripheral blood vessels in collagen diseases *The peripheral blood vessels* Ed J L. Orbison and D Smith Balti more Williams & Wilkins.

Stevens J & Whitefield G A (1966) Synovectomy of the knee in rheumatoid ar thritis *Ann rheum Dis* 25 215

Sumita, M (1912) *Arch clin Chir* 99 755

Zelander T Ekholm R, & Edlund Y (196?) The ultrastructural organization of the rat exocrine pancreas III Intralobular vessels and nerves *J Ultrastructure Research* 7 84

Acta orthop Scandinav 40 300–316 1969

SOFTENING OF THE CARTILAGE AND ARTHRITIS OF THE RHEUMATOID TYPE

Discussion in Relation to Classical Aspects of Chondromalacia

R Lagier & W Taillard[1]

Received 4.11.68

For some years synovectomy has often been used in the treatment of chronic inflammatory rheumatism a reason is the hope that it will interrupt the course of deterioration of the cartilage secondary to synovitis It is therefore logical to make use of the information it provides to study minor or incipient forms of deterioration which herald the advent of the classical lesions in their developed form Such a study is possible in conditions not afforded by post mortem examination and morphological correspondence of cases under clinical study can be detected in fresh material but such evidence must be interpreted within the limits of normal changes in subjects of the same age

The observations reported here were made on patients with arthritis of rheumatoid type the diagnosis of which had been clearly established clinically on joints with a synovitis that had been histologically verified and on hyaline cartilaginous surfaces that exhibited neither patches of ulceration nor pannus (apart from a few slight marginal expansions of connective tissue)

MATERIAL AND METHODS

The clinical material consisted of 5 men and 4 women aged 22 to 58 7 of whom, including 3 who were seronegative had adult rheumatoid arthritis one had ankylosing spondylitis of the Scandinavian type and the 9th juvenile rheumatoid arthritis operated on in adulthood All together 12 synovectomies were performed Most of these operations were performed on the knee and 2 of them were bilateral but in 2 a group of metacarpophalangeal or interphalangeal joint were affected All the joints operated on had chronic synovitis that histologically presented the classic rheumatoid picture (except for the case of sero negative rheumatoid arthritis presented below) The following 4 cases deserve special attention since they are examples of different forms of chronic inflammatory rheumatism

[1] From the Institute of Pathology (Professor E. Rutishauser†) and the Orthopaedic Clinic (Professor W Taillard) University of Geneva

Case G S (CO 66) (pathological report T 6062/66)

A 2? year-old male who for more than one year had had ankylosing spondylitis of the Scandinavian type with swelling of the knees ankles and metatarsophalangeal joints X ray of the knees showed nothing remarkable E.S.R. 17/40 mm (at 1 and 2 hours) Latex test negative for the blood and the synovial fluid of the knee operated on The synovial fluid contained 1?00 leucocytes per mm³ and 31 g/l protein normal mucin test.

The right knee was operated on because of recurrent hydrarthrosis. Macroscopically and microscopically the synovial membrane showed the characteristics of rheumatoid synovitis (Figure 1A) but it was worthy of note that the hyperplasia was less marked than it usually is in rheumatoid arthritis

Case N L.R (CO 66) (pathological report T 10970/66)

A male aged 49 who had had seropositive rheumatoid arthritis since the age of 20 X ray of the vertebral column and sacro iliac joints excluded ankylosing spondylitis Both knees were the site of recurrent fluid effusions but no lesion was radiologically demonstrable E.S.R. 40/73 mm (at 1 and 2 hours) Latex test positive for the blood and the synovial fluid of the knee operated on The synovial fluid contained 13 200 leucocytes per mm³ and 49 g/l protein mucin test abnormal.

The right knee was operated on The synovial membrane exhibited the macroscopic and microscopic characteristics of rheumatoid synovitis

Case C.M (CO 66) (pathological report T 11 175/66)

A female aged 54 had had seronegative rheumatoid arthritis of the wrists and knees since the age of 40 There had been recurrent effusions into the knees since the onset of the disease but no change in the joint spaces was radiologically demonstrable. E.S.R. 17/40 mm (at 1 and 2 hours) Latex test negative in the blood and the synovial fluid of the knee operated on The synovial fluid contained 900 leucocytes per mm³ and 37 g/l protein mucin test normal.

The right knee was operated on and the synovial membrane was found to be only slightly thickened mostly smooth but with fine villosities in some parts. The difference from classical rheumatoid synovitis was even more obvious under the micro cope (Figure 1C and D)

Case F.S (CO 66–67) (pathological reports T 1? 935/66 and T 3030/67)

A male aged 24 who had since the age of 14 months had juvenile rheumatoid arthritis of the wrists hands ankles and knees no roentgenologic change of the knees E.S.R. 56/88 mm (at 1 and 2 hours) Latex and haemagglutination tests of the blood negative

The first synovectomy was performed on the r ght knee. The synovial fluid contained 38 400 leucocytes per mm³ and 4? g/l protein the latex test was negative and the mucin test normal. Macroscopically and microscopically the synovial membrane exhibited the characteristics of fibrinous rheumatoid synovitis

Synovectomy of the left knee was carried out 4 months later The synovi l fluid contained 41 600 leucocytes per mm³ and 55,5 g/l protein the latex test was negative and the mucin test was slightly abnormal. At the same operation synovectomy of the metacarpophalangeal joints of the two thumbs was performed. The synovial membranes of these joints exhibited macroscop cally and microscopi ally

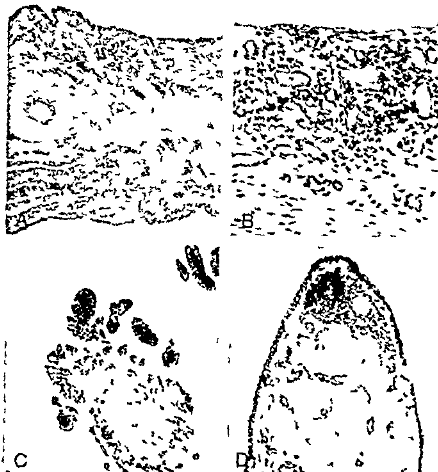


Figure 1 *Different appearances of chronic synovitis observed in the cases studied in this paper*

(A) T 6062/66 (haematoxylin eosin × 59) Ankylosing spondylitis of the Scandinavian type Synovial fringe with synoviocytes showing very little hyperplasia Fairly scanty lympho plasmocytic infiltration A blood vessel with thickened fibrous wall is noticeable

(B) T 3080/67 (haematoxylin eosin × 131) Juvenile rheumatoid arthritis of the right knee Wall of synovial membrane with no hyperplasia of the marginal layer of synoviocytes but with new vessels and infiltration of lympho plasmocytes (mixed with some polymorphonuclear leucocytes)

(C) and (D) T 11175/66 (haematoxylin eosin × 71 × 86) (C) Small synovial fringe with moderate papillary hyperplasia of synoviocytes this hyperplasia is dissociated from a lympho plasmocytic infiltration not visible in this microscopic field (D) Extremity of fatty fringe with slight nodular lympho-plasmocytic infiltration noticeable Very little hyperplasia of the synoviocytes.

For the cases denoted by (A) and (B) more classic pictures of hyperplastic rheumatoid synovitis are to be found with fibrin in case T 3080 67 (ref Figure 1 of study no 40 of the list of references for case T 6062/66) Figures (A) and (B) therefore clearly show that slighter degrees of synovitis existed in those cases

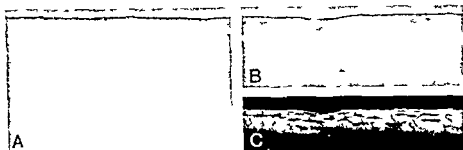


Figure 9 T 3080/67 (toluidine blue × 49) Juvenile rheumatoid arthritis Specimen of softened patellar cartilage from the left knee

(A) Structure normal but loss of polysaccharide substance as shown by disappearance of metachromasia

(B) and (C) Section adjacent to and analogous to the previous one photographed by (B) normal light and (C) polarized light Examination with polarized light shows fine superficial fissures not visible with normal light corresponding to the separation of the arciform collagen fibres Even if they are artefacts due to the histological technique employed they represent the lines of least resistance Similar appearances may sometimes be seen in cartilage considered normal even in young subjects

the characteristics of rheumatoid synovitis (Figure 1B) that of the knee being very fibrinous

The specimens of softened cartilage in these 4 cases were taken from the central part of the patella from the hyaline cartilage and at a certain distance from the edges so as to exclude any possible slight extension of the synovial membrane From this study therefore we eliminated marginal specimens that had been taken for the study of slight pannus that had appeared without infiltration of inflammatory cells Moreover in these marginal specimens the structure of the proper cartilaginous matrix showed no fundamental change in relation to the rest of the joint cartilage

The specimens were fixed in 4 per cent formol and embedded in paraffin We do not think that such fixation impairs the histological demonstration of the acid polysaccharides (13) The sections were stained by different methods haematoxylin eosin van Gieson toluidine blue (1 per cent aqueous solution at pH 4 during 6 hours) Alcyan blue and Gomori s silver impregnation. The study was completed by examining the sections in polarized light

Also specimens of softened patellar cartilage from 7 subjects in whom the diagnosis of rheumatoid arthritis had been formally excluded were studied under corresponding conditions.

OBSERVATIONS

In all the cases but one palpation of the accessible cartilaginous surfaces during the course of the operation revealed more or less marked

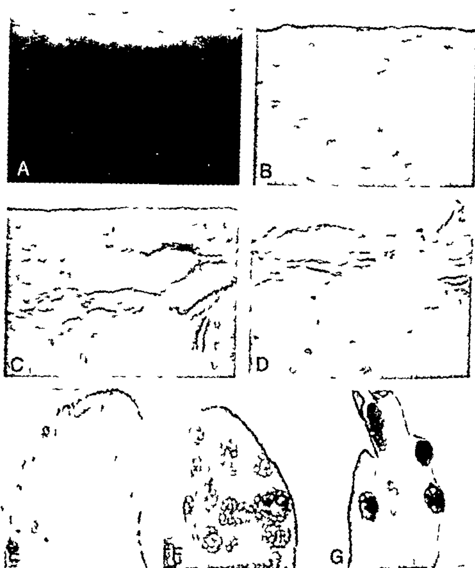


Figure 4 Various appearances of cartilage observed in knees showing the clinical characteristics of chondromalacia patellae after trauma but without rheumatoid disease

(A) Twenty two year old woman who had twisted her left knee several months earlier The operation revealed patellar chondromalacia with chronic synovitis and effusion

(B) to (G) Thirty five year old man who had twisted his left knee on several occasions The operation showed chondromalacic lesions on the lateral and medial aspects of the cartilaginous surface of the patella and the anterior aspect of the medial femur condyle

(A) T 6443/67 (toluidine blue × 44) Specimen of patellar cartilage Normal

stages of this development some of the sections containing several areas of cartilage with the structure fully preserved and with or without the normal complement of polysaccharides

DISCUSSION

The number of cases observed was only 12 in 4 of which a systematic histological study was made of the chondromalacia found They are therefore of interest only as a guide in an analysis of a larger amount of material to be obtained in the future From this point of view they deserve discussion in the light of three considerations

- the normal constitution of the hyaline cartilage of the joint
- the concept of chondromalacia in general
- the influence of rheumatoid synovitis on cartilaginous tissue

---

structure and staining in this section with metachromasia of the perpendicular one (The metachromasia is reduced in parts of specimens taken from adjacent areas)

(B) T 4686/67 (toluidine blue × 60) Specimen of cartilage from the lateral aspect of the patella Normal structure Loss of polysaccharide substance as shown by disappearance of metachromasia

(C) T 4686/67 (toluidine blue × 60) Specimen from anterior aspect of medial femur condyle Metachromasia lost but surface normal Fine furrowing in the depth and sporadic replacement of normal by fibrocytic structure

(D) T 4686/67 (toluidine blue × 60) Section adjacent to that of (C) The changes previously observed here affect the surface area.

(E) T 4686/67 (toluidine blue × 60) Specimen from the lateral aspect of the patellar cartilage This piece of cartilage has lost its metachromasia and it frayed easily when subjected to laboratory techniques Several small areas of chondrocyte proliferation in places emphasized by a very basophil metachromatic halo

(F) T 4686/67 (toluidine blue × 60) Specimen from the lateral aspect of the patellar cartilage Very reduced metachromasia and many areas of chondrocyte proliferation

(G) T 4686/67 (toluidine blue × 60) Specimen from the lateral aspect of the patellar cartilage Much reduced metachromasia. Isogenic chondrocyte groups emphasized by very basophil metachromatic haloes

N B As in Figure 2 evidence of the significance of the loss of metachromasia is provided by the successful staining of areas of normal cartilage subjected to the same laboratory techniques and conditions (Some are to be seen on the same sections as those in the figures)

1 *The Normal Hyaline Cartilage of the Joint*

The framework of normal cartilage consists of collagen fibres the arciform arrangement of which has been described in a classical study by *Benninghof* The fibres are embedded in ground substance containing combinations of proteins and neutral and acid polysaccharides (PP) The latter are the best known partly because of studies of costal cartilage, they are chondroitin sulphuric acid the level of which falls with age and kerato sulphuric acid the level of which rises until about the age of 25 years and then remains fairly constant (26) These acids are produced by the chondrocytes and condition the hydration of the cartilage by bound water (26)

The acid polysaccharides are responsible for cartilage metachromasia which is normally clearly visible in the perpendicular zone and not in the tangential and transitional zones (Figure 1 A) (19) the same applies to stainability with Alcian blue The whole complex exhibits a consistency whose elasticity can be measured by elastometry (19) The consistency varies according to the site and seems to be related to the mechanical stress

Hirsch has defined normal articular cartilage as follows Thus when I say healthy cartilage I mean cartilage in which chondroitin sulphuric acid is retained in the perpendicular zone *i e* in most of the cartilage and where its content only varies in the tangential and transitional zones Cartilage of this kind has been shown to have a typical elasticity curve

2 *The Concept of Chondromalacia*

(a) *Definition* First recognized by *Büdinger* in 1906 softening of the articular cartilage has been mostly studied in the patella where it occurs most commonly and earliest Various terms have been proposed for it in the German literature traumatische Knorpelrisse (*Büdinger*) (7) fissurale Knorpeldegeneration (*Fauen*) (25) Chondropathie der Patella (*Frund*) (14) But it is better known under the etymologically descriptive name of chondromalacia usually applied to the patella

The term chondromalacia which had already been used by *Aleman* since 1917 appeared for the first time in the literature in 1924 in a paper by *Konig* (cit in 20) The definitions of these authors agree with that given by *Hirsch* in 1944 By chondromalacia of the patella I mean all changes in the patellar cartilage revealed in softening fissuring or tuft formation or a combination thereof whether or not any deformity

in the joint or subchondral reaction is present *Hirsch* thus compared malacic cartilage with normal cartilage on the basis of histological stain ing supplemented by chemical titration and elastometric measurements defining more accurately the impressions furnished by palpation By malacic cartilage I mean herein cartilage which has a poorer pressure elasticity than normal cartilage and in which the reduction of chon droitin sulphuric acid extends down into the perpendicular zone (19)

(b) *Macroscopic appearance* In fact the concept of chondromalacia covers two appearances clearly distinguished by several authors (14 19 32 37) In the first the cartilage is simply softened In the second it presents surface fraying or fissures [hence the expression Knorpel risse (7) or fissurale Knorpeldegeneration (25)] The fissures may be superficial (19) leaving a macroscopically healthy base after surgical excision of specimens but they may also be deeper extending down to the subjacent bone (7 45)

The latter form is usually explained as a development of the former (7 14 19 37) *Budinger* thus described the cartilage on the periphery of a fissured zone eigentumlich verändert weich hydropisch ge schwollen und hat den Glanz verloren (7) *Hirsch* thought that the fissures appeared at the junction of areas of cartilage of different consi stency and summed up his views as follows It seems probable there fore that in my series cartilaginous fissures were not the primary cause of the patellar chondromalacia They seemed to occur secondarily in already altered cartilage (19)

(c) *Microscopic appearance* The earliest manifestation of chondro malacia as seen in the microscope is a change in the staining charac teristics of the perpendicular zone of the cartilage the basophilia dimi nished (32 45) and Alcian blue stains less well corresponding to a loss of metachromasia with toluidine blue (19) (Figure 4 B) These changes reflect a fall in the level of chondroitin sulphuric acid

The general structure is preserved as can be confirmed by examination with polarized light The cells may be normal in their arrangement (45) or sometimes already show a certain amount of irregular proliferation

The next manifestation is uncovering of the fibrils with fissure formation or even the appearance of small cavities (19 25 32 45) (Figure 4 C and D) Examination with polarized light clearly reveals these changes as well as an important characteristic noticeable even in the early forms the disappearance of the hyaline structure of the cartilage begins with dissociation of the fibrils and leads to its replace ment by a more or less fibrous conjunctival structure (25) This process can also be observed by silver impregnation

The cells take part in this transformation Small nests of chondrocytes proliferate mainly on the margin of the fissures (Figure 4 I and F) or the chondrocytes are replaced by fibroblasts or fibrocytes (25) These cellular changes correspond to the structural dedifferentiation referred to above

The changes with fissure formation are also accompanied by loss of metachromasia histologically reflecting the fall of chondroitin sulphuric acid observed with chemical methods (5 29) In some places however nests of proliferating chondrocytes show hyperbasophilia with strong metachromasia corresponding to overproduction of sulphated acid polysaccharides (Figure 4 G) This was also observed in cartilage in rheumatoid diseases (41) *Collins* showed this distinctly by an increased 35 S fixation he noticed such appearances in fissured cartilage and considered them secondary to changes of the surrounding matrix (10)

Research by *inter alia Owre* has shown that the proportion of microscopic lesions *is higher than the proportion of macroscopic lesions (32)*

(d) *Consequences* Because of this loss of elasticity with the fall in the level of chondroitin sulphuric acid and often fissure formation the cartilage no longer fulfils its function as an elastic buffer (19) the pumping mechanism that ensures that it receives its nutrition from the synovial fluid is uncertain Fragmentation and even disappearance of the cartilaginous covering may then occur creating the morphological *conditions for a 'modelé arthrosique'* (23) In *its completed form* this osteo arthrosis is characterized by remodelling of the underlying bone osteophyte formation visible radiographically, and often associated synovitis (14 32 45)

Several authors have stressed the possibility of chondromalacia of the patella being a pre arthrotic condition (14, 37 45) This possibility is reflected in the time interval observed in anatomical studies of large series of knees between the maximum age for osteo arthrosis and that for chondromalacia (37)

(e) *Origin and nosological status* Systematic study of large series of joints in subjects of different ages even with no obvious clinical manifestations has shown *how common chondromalacia is especially in* the knee and primarily in the patella The chief manifestations in the patella are on the medial aspect which is particularly subject to mechanical stress (31 43) This suggests that mechanical stresses may play a part in the pathogenesis of the lesions just as topographic studies of chondromalacia suggest in other joints

The changes are early they have been shown in many post mortem statistics to appear as soon as the second decade (3 18 21 32 37) *Owre*, who distinguishes between oedematous and fissural forms has seen none of the latter below the age of 20 years but he has seen the former in 5 out of 18 subjects of a group aged less than 20 years all below the age of 14 years

The daily experience of surgeons also testifies to the frequency of chondromalacia particularly in young patients in 220 arthrotomies performed mostly on patients between 20 and 30 years of age for various indications *Aleman* noticed chondromalacia in 33 per cent of the cases

Surgeons have also observed that certain young patients suffering from pain after local trauma presented at operation more or less marked chondromalacic lesions of the patella Their observations explain some of the various terms that have been used traumatische Knorpelrisse (7) traumatische Chondropathie der Patella (14) Chondromalacia post traumatica patellae (1) This evidence while not excluding the possibility of traumatic fissuring in healthy cartilage (19) provides a justification for the view that the condition is due to the association of trauma with a previous predisposing change (7 25 45) *Wiles et al* sum up this view as follows " trauma is of importance more often as an aggravating than as a primary factor and (that) it acts by disrupting already degenerate cartilage (45)

The condition forms the nosological entity known under the name of chondromalacia patellae Its clinical importance is dependent on the extent of the changes in the cartilage and especially on the subsequent synovial reaction (1 25 30 45) Early chondrectomy has been advocated for its treatment and to prevent it to a certain extent from developing into an osteo arthrosis (1 6 25 30 44 45)

3 *Influence of Rheumatoid Synovitis on Cartilage*

The influence of the rheumatoid synovial membrane on cartilage has been suspected for a long time (39) and it has been the subject of more exact study in the last few years especially since lysosomal enzymes have been revealed in it and in the corresponding joint fluid (2 16 27 33 36 42)

Thinning and erosion may indicate the action of rheumatoid synovitis on collagen substance and in fact a collagenase has been detected in cultures of rheumatoid synovial membrane (11) But this is not the type of change that we are considering here

Of more interest is the action on the ground substance or, to be precis on the *protein polysaccharide complexes (PP) Ziff, Gribetz and Lo* *palluto* have shown that extract of rheumatoid synovial membrane (a also of leucocytes) degrades a cartilage *mucoprotein* this action i destroyed by heat (46) *In vitro* the degradation of cartilage protein polysaccharide complexes has been achieved by lysosomal extracts (12 or purified fractions (38) and by proteolytic enzymes under certai experimental conditions The *in vivo* or *in vitro* action of plasmin blood protease (22) is analogous to that of non activated papain (1) it affects the protein moiety and liberates chondroitin sulphuric acid Nevertheless a degradation of chondroitin-sulphuric acid due to en zymes is considered as possible (4 5 and 8)

It is also possible that cartilage deterioration may also be due beside to changes induced in the synovial fluid by rheumatoid synovitis mani fested in particular by a fall in viscosity (9 36) This could act b changing the lubrication of friction surfaces and the nutrition by im bibition of the cartilage (17 36)

These changes are thus capable of destroying the equilibrium of the collagen fibre arcades, which depends on their being embedded in ground substance The result perhaps comparable to the one observed in cultured cartilage (34) is fibril formation and cellular changes Thus a process takes place analogous to that postulated for other chondro-malacias observed in joints without rheumatoid synovitis

CONCLUSION

The concept of a non specific chondromalacia induced by rheumatoid conditions is suggested by our observations in synovectomized joints and supported by *in vivo* or *in vitro* biological data Its demonstration would be important in providing an explanation at least in part for the origin of the classical developed lesions (9 15 35) particularly those of the connective layer known as pannus The existence of such a process could also explain the appearance of a "modele arthrosique" in joints with rheumatoid arthritis on which synovectomy had previously been performed at an early stage with apparent clinical success

Because it would act on complexes with a much more rapid turnover than the adjacent collagen (28 36) the existence of such a process might make possible an early therapeutic attack One should recall however that the origin of this process is perhaps *not only* in synovitis but also in chondrocytic changes

Nevertheless before such a conclusion could be drawn the concept of rheumatoid chondromalacia would require much more study Research is needed to establish whether it has characteristics of its own (particularly in relation to site and extent) and to define more closely the range of chondromalacias of other types (particularly in relation to frequency)

It is important then that surgeons when they carry out arthrotomies on patients with or without chronic inflammatory rheumatism should make an effort to produce the detailed information required

SUMMARY

Twelve operations of synovectomy were performed on nine patients with various rheumatoid conditions (adult rheumatoid arthritis ankylosing spondylitis juvenile rheumatoid arthritis) They concerned the knees except in two cases where groups of finger joints were operated on

Softened areas were frequently observed on cartilaginous surfaces with the same macroscopic and microscopic characteristics as in other forms of chondromalacia

These observations are to be compared to experimental data concerning the role of enzymatic factors in the degradation of protein polysaccharides complexes of cartilage The existence of such a process secondary to rheumatoid synovitis (perhaps yet to chondrocytic changes) could explain more advanced articular lesions Nevertheless before this concept is accepted further observations are needed to establish the comparative characteristics of chondromalacia with or without rheumatoid conditions

RESUME

Douze synovectomies ont été pratiquees chez neuf malades souffrant de différents états rhumatoïdes (arthrite rhumatoide de l adulte spondylarthrite ankylosante arthrite rhumatoide juvenile) Il s agissait du genou sauf dans deux cas ou l intervention a porte sur des groupes d articulations digitales

Des plages de ramollissement ont frequemment eté observees sur les surfaces cartilagineuses avec les memes caractéristiques macroscopiques et microscopiques que dans d autres formes de chondromalacie

Ces observations sont a rapprocher de certaines donnees experimentales concernant le role des facteurs enzymatiques dans la degradation

des complexes protéine polysaccharide du cartilage. L'existence d'un tel processus secondaire à la synovite rhumatoïde (peut-être aussi à des modifications chondrocytaires) pourrait expliquer des lésions articulaires plus avancées. Néanmoins avant d'admettre cette conception de plus amples observations sont nécessaires pour établir les caractéristiques comparatives de la chondromalacie avec ou sans synovite rhumatoïde.

ZUSAMMENFASSUNG

Zwölf operative Synovektomien wurden bei neun Patienten durchgeführt, die an verschiedenen rheumatoiden Leiden erkrankt waren (pcP des Erwachsenen, Spondylarthritis ankylopoietica, pcP des Jugendlichen). Abgesehen von zwei Fällen, wo man die Synovektomie an einzelnen Fingergelenken ausführte, betraf sie in den übrigen Fällen das Kniegelenk.

An Gelenkoberflächen fielen beim Knorpel häufig erweichte Herde auf, die die gleichen makro- und mikroskopischen Kennzeichen aufwiesen, wie jene anderer Chondromalazieformen.

Diese Beobachtungen dürften mit gewissen experimentellen Daten in Einklang gebracht werden, insbesondere was den durch gewisse enzymatische Faktoren bedingten Abbau von Protein-Polysaccharidkomplexen des Knorpels anbelangt. Das Vorhandensein eines solchen Vorganges sekundär nach einer rheumatoiden Synovitis, vielleicht auch nach Knorpelzellveränderungen, könnte fortgeschrittenere artikuläre Schäden erklären. Bevor man aber eine solche Auffassung zulässt, sind weitere vergleichende Beobachtungen notwendig, um die Charakteristiken von Chondromalazien mit und ohne rheumatoiden Synovitiden feststellen zu können.

REFERENCES

1. Aleman, O. (1928). Chondromalacia post traumatica patellae. *Acta chir. scand.* 63, 149–190.
2. Barland, P., Novikoff, A. B. & Hamerman, D. (1964). Fine structure and cytochemistry of the rheumatoid synovial membrane with special reference to lysosomes. *Amer. J. Path.* 44, 853–866.
3. Bennett, G. A., Waine, H. & Bauer, W. (1942). Changes in the knee joint at various ages with particular reference to the nature and development of degenerative joint disease. 1 vol. Commonwealth Found. New York.
4. Bollet, A. J., Bonner, W. M. & Nance, J. L. (1963). The presence of hyaluronidase in various mammalian tissues. *J. biol. Chem.* 238, 3522–3527.
5. Bollet, A. J., Handy, J. R. & Sturgill, B. J. (1963). Chondroitin sulfate concentration and protein polysaccharide composition of articular cartilage in osteoarthritis. *J. clin. Invest.* 42, 853–859.

6 Bronitsky J (1947) Chondromalacia patellae *J Bone Jt Surg* 29 931–945
7 Buedinger K. (1906) Ueber Ablosung von Gelenkteilen und verwandte Prozesse *Dtsch Z Chir* 84 311–365
8 Chrisman O D (1964) The ground substance of connective tissue a review of some recent advances in normal and pathologic physiology of the muco polysaccharides *Clin orthop* 36 184–193
9 Collins D H (1949) The pathology of articular and spinal diseases 1 vol 331 p E Arnold London
10 Collins D H & Meachim G (1961) Sulphate (35 SO4) fixation by human articu lar cartilage compared in the knee and shoulder joints *Ann rheum Dis* 20 117-12?
11 Evanson J M., Jeffrey J J & Krane S M (1967) Characterization of a colla genolytic enzyme from cultures of rheumatoid synovium. *Arth a Rheum* 10 277
12 Fell H B & Dingle J T (1963) Studies on the mode of action of excess of vitamin A Lysosomal protease and the degradation of cartilage matrix. *Biochem J* 87 403–408
13 Foldes I Modis L & Suveges I (1964) Metachromasia in cartilaginous tissues *Acta morph Hung* 13 43–50
14 Prund, H (1926) Traumatische Chondropathie der Patella ein selbstandiges Krankheitsbild *Zbl Chir* 12 707–710
15 Gardner D L. (1965) Pathology of the connective tissue diseases 1 vol. 456 p Edward Arnold London
16 Hamerman D., Sandson J & Schubert M (1963) Biochemical events in joint disease *J chron Dis* 16 835–852
17 Hamerman D & Schubert M (1962) Diarthrodial joints an essay *Amer J Med* 33 555–590
18 Heine J (19?6) Ueber die Arthritis deformans *Virchows Arch path Anat* 260 5?1–663
19 Hirsch C. (1944) A contribution to the pathogenesis of chondromalacia of the patella A physical histologic and chemical study *Acta chir scand* 90 suppl. 83 106 p
20 Karlson S (1940) Chondromalacia Patellae *Acta chir scand* 83 347–381
21 Keefer C S Parker F jr., Myers W K & Irwin R L. (1934) Relationship be tween anatomic changes in knee joint with advancing age and degenerative arthritis *Arch int Med* 53 325
22 Lack C H Anderson A J & Ali S Y (1961) Action of plasmin on cartilage matrix in vivo *Nature* (Lond.) 191 1402 1403
23 Lagier R. (1965) Le model arthrosique" au niveau de l epaule In "Problemes actuels de rhumatologie publ by W M Zinn 1 vol 342 p Zollikofer & Co St Gall pp 229–247
24 Lannin F (1959) Rehabilitation of knee meniscus injury with associated mala cia of the patella *J amer med Ass* 171 1662–1664
25 Lawen A (1925) Knorpelresektion bei fissuraler Knorpeldegeneration der Pa tella Eine Fruhoperation der Arthritis deformans *Bruns Beitr klin. Chir* 134 265–307
26 Linn F C. & Sokoloff L. (196) Movement and composition of interstitial fluid of cartilage *Arth a Rheum* 8 481–494

27 Luscombe M (1963) *Acid phosphatase and catheptic activity in rheumatoid synovial tissue* *Nature* (London) 197 1010
28 Mankin H J (1967) The structure chemistry and metabolism of articular cartilage *Bull rheum Dis* 17 447–452
29 Matthews B F (1953) *Composition of articular cartilage in osteoarthritis* Changes in collagen/chondroitin sulphate ratio *Brit med J* 2 660–661
30 de Montmollin B (1951) La chondromalacie de la rotule *Rev chir orthop* 37 41–51
31 Outerbridge R E (1961) The etiology of chondromalacia patellae *J Bone Jt Surg* 43 B 752–757
32 Owre A (1936) Chondromalacia patellae *Acta chir scand* 77 suppl 41 159 p
33 Page Thomas D P (1967) The role of lysosomes in rheumatoid disease *Rheumatology* Basel 1 29–50
34 Roulet F (1935) Studien über Knorpel und Knochenbildung in Gewebekulturen Zugleich ein Beitrag zur Lehre der Entstehung der sogenannten Grundsubstanzen *Arch exp Zellforsch* 17 1–4?
35 Rutishauser E Lagier R & Grasset E (1959) Neue Erkenntnisse auf dem Gebiet der Arthrose Arthritis Forschung In K Fr Bauer Medizinische Grundlagenforschung S 293–296 G Thieme Verlag Stuttgart
36 Schubert M & Hamerman D (1964) The functioning of the diffuse macromolecules of joints *Bull rheum Dis* 14 345–348
37 Silfverskiold N (1938) Chondromalacia of the patella *Acta orthop scand* 9 214–223
38 Spilberg I & Weissmann G (1967) Degradation of proteinpolysaccharid (PPL) by purified lysosomes *Arth a Rheum* 10 315
39 Sylven B (1948) Cartilage and chondroitin sulphate III Chondroitin sulphate and inflammatory lesions of cartilage *J Bone Jt Surg* 30 A 158–16?
40 Taillard, W & Lagier R (1967) Softening of hyaline cartilage in chronic inflammatory rheumatism In Synovectomy and arthroplasty in rheumatoid arthritis 2nd International Symposium Basle 1 vol pp 13–?0 ed. by G Chapchal G Thieme Verlag Stuttgart
41 Taillard W & Lagier R. (1968) Chondromalacia and arthritis of rheumatoid type In Early synovectomy in rheumatoid arthritis Symposium held in Amsterdam (april 1967) 1 vol ed by W Hijmans Excerpta Medica Monograph Amsterdam
42 Weissmann G (1966) Lysosomes and joint disease *Arthr a Rheum* 9 834 840 834–840
43 Wiberg G (1941) Roentgenographic and anatomic studies on the femoro patellar joint *Acta orthop scand* 12 319–410
44 Wiles, Ph Andrews P S & Bremner R A (1960) Chondromalacia of the patella a study of the latest results of excision of the articular cartilage *J Bone Jt Surg* 42 B 65–70
45 Wiles Ph Andrews P S & Devas M B (1956) Chondromalacia of the patella J Bone Jt Surg 38 B 95–113
46 Ziff M Gribetz H J & Lospalluto J (1960) Effect of leukocyte and synovial membrane extracts on cartilage mucoprotein *J clin Invest* 39 405–41?

Acta orthop Scandinav 40 317-324 1969

Orthopaedic Department, Ashkelon Government Hospital and Veterinary Institute
Beit Dagan Israel

CARTILAGE EXTRACT IN TREATMENT OF FRACTURES IN RABBITS

H Z Herold T A Nobel & A Tadmor

Received 24 ii 68

Various biological product have been tested for their possible accelerat ing effect on bone healing For the past two years we have been using cartilage and its extracts in the treatment of experimental bone defects The choice of this product was empirical after failure of other mate rials The use of cartilage seemed somewhat logical it being the main constituent of the early callus Recent reports by Prudden (1963) on the favorable influence of cartilage on wound healing further encou raged our experiments

In a series previously reported by us (1967) animals with experi mental bone defects were treated with cartilage in a combined way i e both locally and with subcutaneous cartilage extract injections No statistically significant difference in the time of healing was observed when comparing the treated animals and controls Nevertheless in those cases where the local cartilage did not provoke an inflammatory reaction or an abscess formation union seemed accelerated The present series consists of animals treated exclusively with parenteral cartilage extract thus avoiding any local inflammatory reaction at the fracture site

MATERIAL AND METHODS

To study the possible action of cartilage extracts on bone healing a series of standard bone defects were produced in the radii of rabbits. Each defect consisted of a three millimeter segment removed from the midshaft of the radius the ulna being left intact These standard defects have the advantage that no fixation or splinting are necessary and the incidence of healing is predictable and reproducible

The delay required for the first appearance of callus and that required for full union was determined by serial roentgenograms at weekly intervals (Figure 1) The histology of the callus a fortnight after operation was compared in a group of treated animals and untreated controls.

27 Luscombe M (1963) Acid phosphatase and catheptic activity in rheumatoid synovial tissue *Nature* (London) 197 1010
28 Mankin H J (1967) The structure chemistry and metabolism of articular cartilage *Bull rheum Dis* 17 447–452
29 *Matthews B F (1953) Composition of articular cartilage in osteoarthritis* Changes in collagen/chondroitin sulphate ratio *Brit med J* 2 660–661
30 de Montmollin B (1951) La chondromalacie de la rotule *Rev chir orthop* 37 41–51
31 Outerbridge R E (1961) The etiology of chondromalacia patellae *J Bone Jt Surg* 43 *B* 752–757
32 *Owre A (1936) Chondromalacia patellae Acta chir scand 77 suppl 41* 159 p
33 Page Thomas D P (1967) The role of lysosomes in rheumatoid disease Rheumatology Basel 1 29–50
34 Roulet F (1935) *Studien über Knorpel und Knochenbildung in Gewebekulturen* Zugleich ein Beitrag zur Lehre der Entstehung der sogenannten Grundsubstanzen *Arch exp Zellforsch* 17 1–42
35 Rutishauser E Lagier R & Grasset, E (1959) Neue Erkenntnisse auf dem Gebiet der Arthrose Arthritis Forschung In K Fr Bauer "Medizinische Grundlagenforschung" S 223–296 G Thieme Verlag Stuttgart
36 Schubert M & Hamerman D (1964) The functioning of the diffuse macromolecules of joints *Bull rheum Dis* 14 345–348
37 Silfverskiold N (1938) Chondromalacia of the patella *Acta orthop scand* 9 214–223
38 Spilberg I & Weissmann G (1967) Degradation of proteinpolysaccharid (PP L) by purified lysosomes *Arth a Rheum* 10 315
39 Sylven B (1948) Cartilage and chondroitin sulphate III Chondroitin sulphate and inflammatory lesions of cartilage *J Bone Jt Surg* 30 A 158–172
40 Taillard, W & Lagier R (1967) Softening of hyaline cartilage in chronic inflammatory rheumatism In "Synovectomy and arthroplasty in rheumatoid arthritis " 2nd International Symposium, Basle 1 vol pp *13–20 ed by* G Chapchal G Thieme Verlag Stuttgart.
41 Taillard W & Lagier R (1968) Chondromalacia and arthritis of rheumatoid type *In "Early synovectomy in rheumatoid arthritis Symposium held in* Amsterdam (april 1967) 1 vol ed. by W Hijmans Excerpta Medica Monograph Amsterdam
42 *Weissmann G (1966) Lysosomes and joint disease Arthr a Rheum* 9 834 840 834–840
43 Wiberg G (1941) Roentgenographic and anatomic studies on the femoro patellar joint *Acta orthop scand* 12 319–410
44 Wiles, Ph. Andrews P S & Bremner R A (1960) Chondromalacia of the patella a study of the latest results of excision of the articular cartilage *J Bone Jt Surg* 42 *B* 65–70
45 Wiles Ph Andrews, P S & Devas M B (1956) Chondromalacia of the patella J Bone Jt Surg 38 *B* 95–113
46 Ziff M Gribetz H J & Lospalluto J (1960) Effect of leukocyte and synovial membrane extracts on cartilage mucoprotein *J clin Invest* 39 405–41–

The cartilage extract used in this experiment was prepared from cartilage powder supplied by the Nutritional Biochemicals Company This was mixed with a physiological saline solution so as to obtain a suspension containing 12 5 per cent cartilage After mixing in a shaker for three hours at room temperature the liquid was centrifuged and filtered resulting in a clear transparent fluid This was bottled and kept in the freezer till use when mild heating to about 30 facilitated its use for injections

Controls

Eighteen adult female rabbits weighing 4 ± 0.2 kilograms each had both their forelegs operated, producing a series of thirty six standard three millimeter radial defects One animal sustained a subsequent fracture of the ulna, thirty five legs being left for evaluation of the healing time

Cartilage Treated

Twenty three female rabbits of similar weight were operated to produce the same bone defects as in the controls Each animal in this group was given subcutaneously ten milliliters of the 12 5 per cent cartilage extract in saline every other day for a fortnight and twice in the third week after the operation One animal died subsequently before bone healing and one sustained a fracture of the ulna, forty three bone defects being left for follow up in this group

Pathology

Ten rabbits were operated as above and five treated with cartilage extract One rabbit expired of coccidiosis and the remaining nine were sacrificed fourteen days after the operation their eighteen operated forelegs being used for histological examination of the early callus

RESULTS

X Rays

The time necessary for the first appearance of callus and the time required for complete filling of the defects were studied Table 1 compares the mean healing time in treated rabbits and in untreated controls It is evident that both the appearance of callus and union were quicker in the cartilage treated rabbits

The distribution of cases according to healing time revealed that in six out of thirty five control fractures the first appearance of callus took more than four weeks Among the cartilage treated animals this delay occurred only in one case out of forty three The difference is statistically significant ($\chi^2 = 5.74$ $p < 0.05$) In five of thirty five controls union was complete by five weeks whereas among the treated animals twenty out of forty three fractures were solidly united by this time interval Here again the difference is statistically significant ($\chi^2 = 5.74$ $p < 0.05$)

Table 1. Mean healing time

	No. of legs	First appearance of callus on X rays (weeks)	Complete union (weeks)
Control group	35	3.8 ± 0.9	7.4 ± 2.3
Cartilage treated	43	3.4 ± 0.4	6.3 ± 2
t (Student's test)		2.73	2.22
P		< 0.005	< 0.05

Table 2. Histopathological evaluation of callus two weeks after operation

	No. of bone defects examined	Bone reparation with			Non specific results
		Strong cartilage formation	Medium cartilage formation	Poor cartilage formation	
Controls	10	0	2	7	1 (abscess)
Cartilage treated	8	6	2	0	0

Pathology

Upon dissection at two weeks after operation the bone defects were filled with soft tissue masses protruding from the neighboring bone thus having the aspect of local tumefactions (Figure 2). Microscopic evaluation of the cartilage formation and the progress of healing in treated animals and controls is presented in Table 2. It is evident that callus formation was more advanced at this early stage among the treated animals.

A description of two extreme findings will give a fair representation of the reparative process observed. In the control group the bone defects were filled with loose connective tissue amply vascularized in places. Some fibrous strands were found traversing this connective tissue. Reparation was seen especially subperiostally as well as intramedullarily but was slight in extent with no tendency to unite with the opposite bone end. In the treated group copious cartilage formation with incipient calcium deposits and ossification was observed around each stump. The interval between the sawed bone ends was occupied largely by newly formed cartilage tissue with progressive ossification. The few strands of connective tissue had begun to undergo cartilage metaplasia (Figure 3).

Figure 2 Gross appearance of the pathological specimens
A Dissected mounted forelegs of the rabbits left leg immediately after operation right leg two weeks after operation
B The defect of the radius and the intact ulna
C The macroscopic appearance of the callus







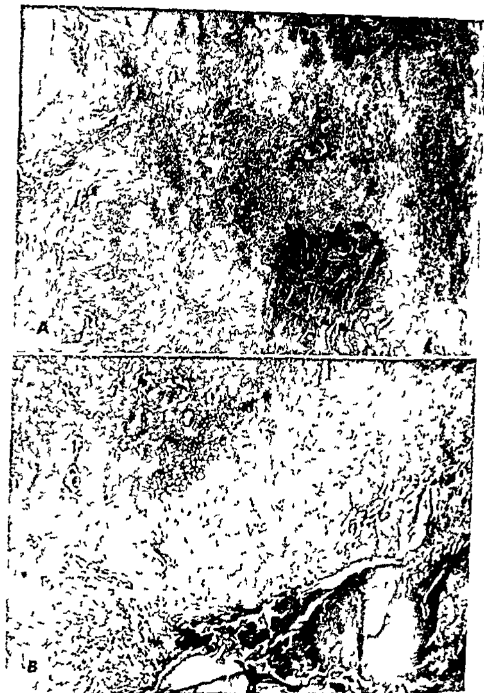


Figure 3 Microscopic appearance of the callus on low magnification A and B = treated animal Strong cartilage formation and beginning ossification in operated area. A × 10 B × 16



Figure 3 Microscopic appearance of the callus on low magnification
C and D = control Connective tissue and poor cartilage formation in the callus
C × 10 D × 10

DISCUSSION

Saline extract of cartilage powder appears to have a favorable influence on the healing of soft tissue wounds when administered locally or parenterally parenteral administration of the extract seems to accelerate bone healing in the rabbit

It is as yet impossible to determine the mechanism of action and the active components of cartilage Histological study of fracture callus in the rabbit indicates that the extract administered has some influence on the early stages of union before calcification

Chondroitin sulphate was reported by Moss (1958) to play a role in inducing ossification On the other hand it was reported by Wolarsky (1965) to have no influence on soft tissue wound healing Its role as the main active component of cartilage extract is improbable since any observable effect of this extract on bone seems to take place before ossification

The possible action of saline cartilage extract on bone healing is far from clear The encouraging findings in the present series justify further research in this field

SUMMARY

Experimental bone defects were produced in the radii of rabbits A series of operated animals was treated with parenteral saline cartilage extract and the healing time compared with untreated controls An earlier appearance of callus and accelerated union were observed in the treated rabbits

REFERENCES

Herold H Z & Tadmor A (1967) Cartilage extracts in the treatment of experimental bone defects results of combined treatment—local and parenteral *Int Surg 48 (1) 17-22*

Moss L M (1958) Extraction of an osteogenic inductor factor from bone *Science* 127 755

Prudden J F Gabriel O & Allen B (1963) The acceleration of wound healing *Arch Surg* 86 157-161

Wolarsky E R Ocampo L & TenEick M L (1965) Effect of chondroitin sulphate on tensile strength of healing wounds *Arch Surg* 91 521 5

Acta orthop Scandinav 40 325–333 1969

Department of Clinical Physiology (Head Prof A Carlsten M D)
and the Department of Orthopaedic Surgery (Head Prof C. Hirsch M D)
University of Goteborg Sweden

THE EFFECT OF PHYSICAL TRAINING IN GIRLS WITH IDIOPATHIC SCOLIOSIS

J Bjure G Grimby & A Nachemson
with the assistance of M Lindh

Received 24 ix 68

As known a lateral curvature of the thoracic spine impairs pulmonary function of the patient (Rieder 1881 Chapman Dill & Graybiel 1939 Bergofsky Turino & Fishman 1959 Mankin Graham & Schak 1964 Fishman 1965 Cotrel 1965) Working capacity and life expectancy were found to be decreased in a recent long term follow up of non treated scoliosis (Nachemson 1968) These patients were followed for 15–40 years and it was found that the pulmonary insufficiency caused by the scoliosis accounted for 100 per cent overmortality compared with normal subjects For subjects with severe thoracic curves this overmortality was about 400 per cent

In the present investigation of a selected group of scoliotic girls ventilatory function and physical fitness were studied in an attempt to find out whether a physical training program could increase the physical performance and thus form a basis for future advice to these severely handicapped patients

MATERIAL

The material consisted of 11 girls aged 16–27 years with idiopathic scoliosis The age the localization of the scoliosis and the degree of the curve measured according to Cobb (1948) are given in Table 1 All the girls had reached skeletal maturity as judged from the iliac apophysis sign (Risser 1964) Some of the patients had been previously operated upon At least 2 years had elapsed between the spinal fusion and this training period. Heart catheterization had been performed 1 3 years previously in cases Nos. 3 5 6 10 and 11 All had normal pressures and flow in the pulmonary circulation at rest and during moderate exercise with the exception of No 11 who had moderate pulmonary hypertension during light work [illegible] pulmonary pressure [illegible]6 mm Hg cardiac output 9 9 l/min [illegible] 0.[illegible] l/min)

Table 1

Pat no	Age (yrs)	Height (cm)	Weight (kg)	Type of curve	Degree (Cobb) of prim curve	Previous therapy (none had had treatment for the proceding 18 months)
1	18	131	40	idiopathic mid thor	100	Milwaukee brace Harrington rod + fusion 3 yrs prev part res of scapula and ribs 2 yrs prev
2	20 5	163	56	idiopathic mid thor	1?0	Plaster corsets Harrington rod + fusion 3 yrs prev part res of scapula 2 yrs prev
3	[illegible]	[illegible]	43	idiopathic mid thor	150	Plaster corsets Milwaukee brace Rib resect 3 yrs prev
4	17	163	[illegible]	idiopathic thoracolumbar	35	Milwaukee brace
5	[illegible]	155	47	idiopathic thoracolumbar	[illegible]	Milwaukee brace Harrington rod + fusion 3 yrs prev Rib resect 2 yrs prev
[illegible]	[illegible]	[illegible]	42	idiopathic mid thor	110	Milwaukee brace Harrington rod + fusion 3 yrs prev
7	16 5	[illegible]	[illegible]	idiopathic mid thor	35	None
[illegible]	17	[illegible]	[illegible]	idiopathic mid thor	30	None
[illegible]	27	[illegible]	[illegible]	idiopathic mid thor	90	Plaster corsets Conventional fusion 3 yrs prev
10	23	[illegible]	[illegible]	idiopathic thoracolumbar	1?0	Plaster corsets Milwaukee brace Harrington rod + fusion 2 yrs prev
11	[illegible]	[illegible]	73	idiopathic mid thor	115	Plaster corsets

METHODS AND PROCEDURE

The dynamic lung volumes (vital capacity and forced expiratory volume in 1 sec) were determined and normal values were predicted for equations published by Berglund Birath Bjure Grimby Kjellmer Sandqvist & Soderholm (1963)

Plasma volumes were measured with I^{131} human serum albumin and the total blood volume calculated using the hematocrit of venous blood

Resting electrocardiograms were recorded with standard extremity leads unipolar extremity leads and five chest (*CR*) *leads* *The patients were then exercised in the* sitting position on an electrically braked bicycle ergometer (Elema Stockholm) with the indifferent electrode on the forehead Step wise increasing work loads were used up to the maximum The expired air was then collected in Douglas bags for the determination of maximal" oxygen uptake The exercise time on each submaximal work load was 6 minutes

All patients had earlier experience in exercise tests Lactic acid was determined one and five minutes after maximal" exercise in prewarmed fingertip blood using the enzymatic method (Lundholm Mohme Lundholm & Vamos 1963)

After about three months of physical training the same studies were repeated

The program aimed at training the patients regularly 3 times weekly for 3 months The average attendance was 24 times (14–35)

The sessions consisted of

A Warming up exercises walking running jogging deep breathing exercises for 3 minutes

B Circle training This was devised to activate large muscle groups The program consisted of six different exercises which were individually programmed ac cording to the capacity of the patient with about 3 minutes work repeated 3 times with a rest interval of 3 minutes The types of exercises used were

1 jumping up and down on a low seat (20 cm)
2 throwing a medicine ball (2 5 kg) against a wall
3 stationary running while keeping the hands on the wall
4 combined arm flinging and knee bending in the supine position
5 skipping
6 "Indian jump

The program was individualized b first testing the maximal number of each exercise that could be performed in one minute During the actual training half the number of each type of exercise was performed in a sequence The time consumed for this and the pulse rate at completion was measured once weekly

C Bicycling The patient was trained for 2 4 minute periods on a work load which gave a heart rate of 160–180 *beats/min except in case No 11 who had* pulmonary hypertension This patient was trained only at intensities which gave heart rates below 140

RESULTS AND DISCUSSION

Table 2 gives the results of spirometry and the maximal exercise test before and after the training period The heart rate at a submaximal

Table 2 Results from dynamic spirometry and maximal exercise test

Patient no		Vital capacity (BTPS) lit	% pred	Forced expiratory volume in one sec (BTPS) lit	% pred	Blood volume lit	Oxygen uptake ml/kg × min	Maximal exercise: Heart rate	Ventilation lit/min	Respir rate	Tidal volume lit	Arterial lactate conc mM/l
1	b	1.1	40	0.9	36	–	–	173	–	–	–	–
	a	1.2	44	1.0	41		–	–	–	–	–	7.9
2	b	2.4	51	2.2	51	3.8	27.3	198	52.3	46	1137	8.3
	a	2.3	49	2.2	51	4.1	45.4	197	88.9	53	1677	7.6
3	b	2.2	53	1.9	48	4.1	29.1	165	4 9	46	938	7.0
	a	2.1	50	1.9	52		30.5	168	41.6	46	948	2.0
4	b	3.6	89	3.5	97	4.2	32.5	194	54.3	38	1429	7.6
	a	3.6	89	3.4	94		33.8	197	60.0	–	–	[illegible]
5	b	2.4	61	2.2	63	3.1	35.0	196	66.5	56	1188	6.8
	a	2.6	67	2.3	66	3.4	35.4	198	61.4	56	1096	7.4
6	b	1.9	44	1.5	42	3.2	27.7	175	38.3	38	1008	4.3
	a	1.9	44	1.5	42	3.0	34.0	187	55.0	49	1135	7.1
7	b	3.4	86	3.4	97	–	34.8	206	–	–	–	4.7
	a	3.4	86	3.4	97	4.7	40.9	206	65.7	29	2266	5.4
8	b	3.5	84	2.5	68	2.6	27.1	185	38.1	34	1121	3.8
	a	3.6	87	2.9	76		37.5	192	65.5	39	1679	8.2
9	b	1	0	1.8	50	3.6	27.6	169	40	–	–	5.4
	a	2	53	1.9	51	4.7	34.7	180	65.1	61	1067	6.1
10	b	2	59	2.2	59	3.0	29.8	193	51.9	40	1299	6.3
	a	2.4	56	2.2	59		35.2	192	59.8	46	1300	6.6
11	b	1.5	41	1.4	43	4.6	–	155	–	–	–	–
	a	1.3	35	1.1	33		29.1	148	29.9	52	575	4.3

b = before training a = after training % pred = % of predicted according to [illegible]

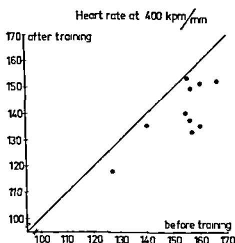


Figure 1 The heart rate at 400 kpm/min before and after training in 10 patients (No 1 could not manage this work load before training) The identity line is drawn

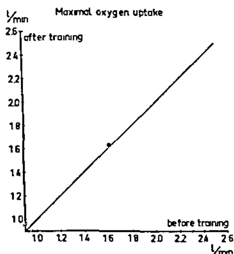


Figure 2 The maximal oxygen uptake before and after training in 9 patients The identity line is drawn

work load (400 kpm/min) and the maximal oxygen uptake before the training are given in Figures 1 and 2 respectively

Normal values for vital capacity (VC) and forced expiratory volume in one second ($FEV_{1.0}$) were recalculated after allowance for the reduced height due to the scoliosis The procedure and the importance of such a correction in about 70 cases with scoliosis has been reported separately (Bjure Grimby & Nachemson 1968) In the present study the actual values are given as percentages of predicted corrected val

ues All patients had lower lung volumes than predicted on an average 60 per cent of predicted VC and 59 per cent of predicted $FEV_{1.0}$ There were no signs of airway obstruction Also in this material large curvatures resulted in low vital capacity which agrees with the findings of among others Mankin et al (1964) and Cotrel (1965)

No abnormal ECG changes were recorded at rest during or after exercise Before training all patients had high heart rates at submaximal exercise (average 153 beats/min at 400 kpm/min) and low maximal oxygen uptake (average 30 ml/kg × min) In a group of females 20-29 years of age I Åstrand (1960) reported a mean value of 40 ml/kg × min The maximal ventilation was in the present group 50 lit/min compared to 70 lit/min in the control group mentioned above The mean respiratory rate was 13 and the mean tidal volume was 1 2 lit (46 per cent of the vital capacity) The maximal heart rate was 187 beats/min which is identical with the figure reported by I Åstrand (1960)

When discussing the working capacity of scoliotic patients some factors must be taken into consideration

A The chest deformity which results in reduced vital capacity and increased work of breathing (Bergofsky et al 1959)
B The small lung which can lead to restriction of the pulmonary vascular bed and pulmonary hypertension
C The long time inactivity which will result in *e g*, decreased muscular strength small circulatory dimensions and inadequate regulation of the circulation during muscular exercise

The results obtained in this group of patients seem to indicate that the ventilatory function is the main limiting factor of physical performance in only a few cases (*e g* patients Nos 3 and 11) and no correlation could be found between maximal oxygen uptake and the reduction in vital capacity This assumption was further supported by studying the effect of training on the maximal oxygen uptake Pulmonary hypertension was observed only in No 11 during moderate exercise with a normal cardiac output Thus in most of these young patients a lack of training is an important factor leading to the reduced physical performance

Training had no effect on VC and $FEV_{1.0}$ As shown in Figure 1 the heart rate at 400 kpm/min decreased in all patients (on an average 13 beats/min) Figure 2 shows that the maximal oxygen uptake increased in nine studied patients (average 22 per cent) but with negli

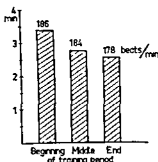


Figure 3 Time required for a series of exercises in the circle training program (see text) at the beginning middle and end of the 3 month training period in patient No 10 The numbers above the bars are the heart rates at the end of each exercise session

gible change in three of the patients (Nos 3 4 and 5) The effect of the training may both be a more adequate regulation of the peripheral blood flow resulting in an increased arteriovenous oxygen difference and an increased stroke volume (Carlsten & Grimby 1966) In the patients in whom there was a substantial increase in the maximal oxygen uptake the ventilation also increased which resulted in an identical ventilation per liter oxygen (35 lit/lit O_2) before and after training On the average the tidal volume during maximal work after training was 54 per cent of the vital capacity In two cases (Nos 2 and 7) values as high as 75 and 67 per cent respectively were noted

The purpose of the physical training was mainly to train the circulatory system It consisted of repeated periods of strenuous exercises lasting 3–4 minutes This time is sufficient to produce high values for oxygen uptake (Åstrand & Saltin 1961 Karlsson Åstrand & Ekblom 1967) During the training period the time for a certain number of exercises decreased An example of this is shown in Figure 3 together with the heart rates at the end of the exercises

Of the eleven patients studied five had previous spinal fusions Eriksson & Foss Hauge (1963) have demonstrated that a spinal fusion will not affect the vital capacity in such patients

The present material is too small to allow definite conclusions on the different effects of physical training in patients with mild moderate or severe scoliosis There is however a trend Some patients who stopped working spontaneously at a relatively low heart rate (*e g* Nos 3 and 11) did so because of a ventilatory limitation of their physical performance which was not improved with training These patients are found among those with the largest curvatures Maximal exercise tests including ventilatory measurements can be valuable in selecting suitable patients for a training program

The low working capacity noted from the start is probably common

in scoliotic patients As mentioned above this can be accounted for by different somatic reasons It is also a common clinical observation that these patients suffer mentally from their deformity Therefore they seldom take part in physical activities The low physical performance limits their vocational ability to very light work (Nachemson 1968) Continuous physical training in selected patients may in some measure be of value leading to higher achievements in their daily work and leisure time

SUMMARY

Eleven scoliotic girls aged 16–27 years were studied with dynamic spirometry and exercise tests including determination of maximal oxygen uptake before and after a 3 month training period

Most patients had low vital capacity (60 per cent of predicted) and maximal oxygen uptake (30 ml/kg $\times$ min)

In two patients the ventilatory function and in one patient moderate pulmonary hypertension were considered important as limiting factors of their physical performance

After training the heart rate at submaximal work load was on the average 13 beats per min lower than before training and the maximal oxygen uptake was increased by 22 per cent Thus in most of these patients the lack of training seems to be an important factor reducing their physical fitness Some of the patients with the largest curvatures had a ventilatory limitation of their physical fitness and did not improve with training

ACKNOWLEDGMENT

This study was supported by grants from the Swedish National Association against Heart and Chest Diseases the Swedish National Research Council (Grant No B 68-[illegible]-2246-01) and the Swedish Polio Foundation

REFERENCES

Berglund E, Birath G, Bjure J, Grimby G, Kjellmer I, Sandqvist L & Söderholm B (1963) Spirometric studies in normal subjects I Forced expirograms in subjects between 7 and 70 years of age Acta med scand 173 185 192

Bergofsky E H, Turino G M & Fishman A P (1959) Cardiorespiratory failure in kyphoscoliosis Medicine 38 263 317

Bjure J, Grimby G & Nachemson A (1968) Correction of b[illegible] in predicting spirometric values in scoliotic patients Scand J [illegible] Lab Invest [illegible] 190–19[illegible]

Carlsten A & Grimby G (1966) *The circulatory response to muscular exercise in man* (Amer Lecture Series Publication No 695) C. Thomas Publ Springfield Illinois

Chapman E M Dill B D & Graybiel A (1939) The decrease in functional capacity of the lungs and heart resulting from deformities of the chest Pulmonocardiac failure *Medicine* 18, 167–202

Cobb J R (1948) Outline for the study of scoliosis *Amer Acad orthop Surg Lect* 5 261–275

Cotrel Y (1965) Conservative management of scoliosis In *Proceedings of a symposium on scoliosis* ed P A Zorab (National Fund for Research into Poliomyelitis and Other Crippling Diseases) Vincent House London pp 18–20

Eriksson H & Foss Hauge M (1963) Cardiopulmonary function in scoliotic patients treated with spinal fusion *Acta orthop scand* 33 395–396

Fishman A P (1965) Pulmonary aspects of scoliosis In *Proceedings of a symposium on scoliosis* ed P A Zorab (National Fund for Research into poliomyelitis and Other Crippling Diseases) Vincent House London pp 52–53

Karlsson J Astrand P O & Ekblom B (1967) Training of the oxygen transport system in man *J appl Physiol* 22 1061–1065

Lundholm L Mohme Lundholm E & Vamos N (1963) Lactic acid assay with L(+) lactic acid dehydrogenase from rabbit muscle *Acta physiol scand* 50 243–249

Mankin H J Graham J J & Schack J (1964) Cardiopulmonary function in mild and moderate idiopathic scoliosis *J Bone Jt Surg* 46 A 53–62

Nachemson A (1968) A long term follow up study of non treated scoliosis *Acta orthop scand* 39 466–476

Rieder J (1881) Die Respirations und Zirculationsstorungen bei Kyphosscoliosis dorsalis Inaug Diss Berlin

Risser C J (1964) Scoliosis past and present *J Bone Jt Surg* 46-A 167–199

Astrand I (1960) Aerobic work capacity in men and women with special reference to age *Acta physiol scand.*, Suppl. 169

Astrand P O & Saltin B (1961) Oxygen uptake during the first minutes of heavy muscular exercise *J appl Physiol* 16 971–976

Acta orthop. Scandinav. 40, 334–345, 1969

Orthopaedic Clinic, University of Gothenburg, Gothenburg, Sweden.

WALKWAY STUDIES AFTER INTERTROCHANTERIC OSTEOTOMY FOR OSTEOARTHRITIS OF THE HIP

CARL HIRSCH & JAN GOLDIE

Received [illegible]5.II.68

In previous studies (*Hirsch* 1960, *Hirsch & Goldie* 1968) attempts have been made to evaluate the results of intertrochanteric osteotomy for osteoarthritis of the hip-joint. In the study of 1960 complete relief of pain was obtained in 30 per cent of the patients but 80 per cent claimed an improvement. In the study of 1968 comprising 102 patients 85 had a decided improvement in spontaneous pain (Table 1) and 71 reported *none or very little weight bearing pain* (Table 2). *The further* analysis in this study was based on criteria commonly used, such as use of walking aids, walking ability, gait without aids, general mobility and objective registration of range of movement. That which attracted greatest interest was the relationship of walking capacity to the use of a cane (Table 3). As is seen only 10 patients of 65 who had used a cane before operation could manage without it postoperatively in outdoor walking. A *more important observation, however, is the fact that of 42 patients* who did not use a cane before operation 25 began to use a stick following the immediate postoperative period. These observations have been interpreted by us as a decreased employment by the patient of the operated leg. In order to further analyse this assumed diminished utilization of the operated leg an attempt has been made to estimate in an objective way how much the operated leg is used in comparison to the non-operated. In this investigation we have studied the maximal time during which the patient loads his operated leg as compared to the non operated and the maximum weight laid on the same leg. To obtain objective measurements of these factors the forces arising between floor and foot in walking was registered. This can be done by

force plates one for each foot With the construction however of electronic walk ways the registration of forces has become much simplified

For this study we have employed an electronic walk way which originally was introduced at our clinic and which has been in use for several years It has been described by *Rydell* (1966) in a study on the forces acting on the hip joint and in the present study found suitable for measuring the use the patient makes of his leg which has been osteotomized for osteoarthritis of the hip-joint

MATERIAL AND METHODS

?8 patients from the stud of 1967 were selected at random They all made a fair representation of the total material Of those to be studied eleven did not use a cane at the time of this investigation (Tables 1 and 2) one additional patient had stopped using the cane Measurements of the forces acting in weight bearing were made on the electronic floor This consists of two 5 metre long parallel walking boards of which one is for each foot (Figure 1) These boards register via force transducers each consecutive step Simultaneously the fore and aft shear and the vertical component of the floor reactions are recorded on a Honeywell measuring bridge For further details about the electronic equipment see *Rydell* 1966 The curve which in this study has attracted greatest attention is that representing the vertical force component during the stance phase The shape of the curve for analysis is

Table 1 Spontaneous pain at follow up 1968

	Male	Female	Total
Improved	40	45	85
Unchanged	1	4	5
Deteriorated	5	7	1?
Total	46	56	102

Table 2 Weight bearing pain at follow up 1968

	Male	Female	Total
Improved	33	38	71
Unchanged	5	11	16
Deteriorated	8	7	15
Total	46	6	10?



Figure 3 a Slight osteoarthritis left hip in 66 year old female. Considerable night pain, weight bearing pain and limping. Limited range of motion. Strong candidate for intertrochanteric osteotomy

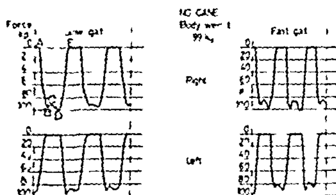


Figure 3 b Gait curve of patient in 3 a

			left leg	right leg
Max. loading force / Body weight	I	slow gait	[illegible]	0.95
	II	fast gait	[illegible]	0.99
Max. loading B–D		slow gait	[illegible]	[illegible]
		fast gait	[illegible]	0.55
Time of loading A–E		slow gait	[illegible]	[illegible]
		fast gait	[illegible]	0.85
Planimetric evaluation		slow gait	[illegible]	8.5
		fast gait	[illegible]	6.5

RESULTS

The Whole Group Representing Cane Bearers and Non Cane Bearers

The maximal loading force (P) in relation to the bodyweight (W)

Without a cane	operated side	non operated side
slow gait	$\frac{P}{W} = 1\ 014 \pm 0\ 060$	$\frac{P}{W} = 1\ 0[illegible]3 \pm 0\ 051$
fast gait	$\frac{P}{W} = 1\ 115 \pm 0\ 097$	$\frac{P}{W} = 1\ 152 \pm 0\ 081$
With a cane		
slow gait	$\frac{P}{W} = 0\ 861 \pm 0\ 091$	$\frac{P}{W} = 0\ 993 \pm 0\ 047$
fast gait	$\frac{P}{W} = 0\ 897 \pm 0\ 104$	$\frac{P}{W} = 1\ 050 \pm 0\ 098$

The relation of the time (B–D) of maximal loading

Without a cane	operated side	non-operated side
slow gait	0 500 ± 0 114	0 571 ± 0 1[illegible]1
fast gait	0 356 ± 0 118	0 413 ± 0 0[illegible]1
With a cane		
slow gait	0 472 ± 0 054	0 556 ± 0 073
fast gait	0 368 ± 0 13[illegible]	0 447 ± 0 104

The relation of the time of loading i e distance A–E

Without a cane	operated side	non operated side
slow gait	1 006 ± 0 2[illegible]7	1 104 ± 0 189
fast gait	0 680 ± 0 036	0 697 ± 0 0[illegible]0
With a cane		
slow gait	1 014 ± 0.318	1 189 ± 0 148
fast gait	0 8[illegible]6 ± 0 34	0 [illegible] ± 0 [illegible]01

The planimetric evaluation of the complete stance phase curve including maximal and minimal force points

Without a cane	operated side	non-operated side
slow gait	5.31 ± 1.57	6 03 ± 1 63
fast gait	3 93 ± 0 91	4 56 ± 1 07
With a cane		
slow gait	4 61 ± 0 63	6 63 ± 1 14
fast gait	3 77 ± 0 76	[illegible]1[illegible] ± 0 9[illegible]

Group Using a Cane Postoperatively

The maximal loading force (P) in relation to bodyweight (W)

Tests *without* a cane	operated side	non operated side
slow gait	$\frac{P}{W} = 0\ 999 \pm 0\ 0[illegible]1$	$\frac{P}{W} = 1\ 00[illegible] \pm 0\ 067$
fast gait	$\frac{P}{W} = 1\ 024 \pm 0\ 09[illegible]$	$\frac{P}{W} = 1\ 0[illegible]9 \pm 0\ 120$
Tests *with* a cane	operated side	non-operated side
slow gait	0 920 ± 0 110	0 9[illegible]3 ± 0 140
fast gait	0 939 ± 0 141	1 0[illegible]8 ± 0 135

The relation of the time B D of maximal loading

Tests *without* a cane	operated side	non-operated side
slow gait	0 367 ± 0 112	0 433 ± 0 092
fast gait	0.335 ± 0 094	0.364 ± 0 081
Tests *with* a cane	operated side	non-operated side
slow gait	0 494 ± 0 101	0 455 ± 0 153
fast gait	0 420 ± 0 0[illegible]9	0 43[illegible] ± 0 0[illegible]

The relation of the time of loading *i e* distance A I

Tests *without* a cane	operated side	non operated side
slow gait	1 0[illegible]1 ± 0 218	1 0[illegible]1 ± 0 233
fast gait	0 812 ± 0 236	0 731 ± 0 198
Tests *with* a cane	operated side	non operated side
slow gait	1 078 ± 0 180	1 039 ± 0 199
fast gait	0 819 ± 0 058	0 8[illegible] ± 0 169

Figure 4 a 60 year old male with osteoarthritis of left hip Intertrochanteric osteotomy with Wainright nail in July 1965 Started weight bearing in June 1966 without a cane and has not used one since then Completely free of symptoms X ray from January 1968



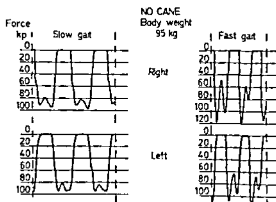


Figure 4 b Gait curve of patient in 4 a from June 1967

		operated side	non operated side
$\frac{\text{Max. loading force}}{\text{Body weight}} = \frac{P}{W}$	slow gait	0.96	0.99
	fast gait	1.01	1.08
Max loading B D	slow gait	0 43	0 48
	fast gait	0.33	0 3
Time of loading A–E	slow gait	1 13	1 14
	fast gait	0 60	[illegible]
Planimetric evaluation	slow gait	7.8	[illegible]
	fast gait	4 7	4 7

The planimetric evaluation of the complete stance phase curve including maximal and minimal force points

Tests without a cane	operated side	non-operated side
slow gait	5.17 ± 1.418	5.25 ± 1.051
fast gait	4.07 ± 1.257	4.47 ± 1.055

Tests with a cane	operated side	non-operated side
slow gait	5.4 ± 1.418	5.66 ± 1.442
fast gait	4.09 ± 1.100	4.71 ± 0.917

It should be mentioned that of the patients in this study eleven do not use a cane in everyday walking. Their respective values, which have been included in the overall estimation, show lesser differences between operated and non-operated side and have been separately estimated as seen by the following calculations.

Group Not Using a Cane Postoperatively

Maximal loading force (P) in relation to bodyweight (W)

	operated side	non-operated side
slow gait	$\frac{P}{W} = 1.070 \pm 0.051$	$\frac{P}{W} = 1.018 \pm 0.049$
fast gait	$\frac{P}{W} = 1.114 \pm 0.052$	$\frac{P}{W} = 1.121 \pm 0.085$



Figure 5a. [illegible] year old female with osteoarthritis of right hip. Intertrochanteric osteotomy with Wainwright nail in April 1965. X ray from April 1967. Patient improved but still has slight weight bearing pain and has to use a cane permanently. Osteotomy completely healed.

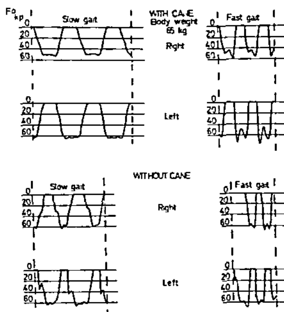


Figure 5 b Gait curve of patient in 5 a from June 1967

		operated side	non operated side
Without a cane			
$\frac{\text{Max loading force}}{\text{Body weight}} = \frac{P}{W}$	slow gait	0.97	0.99
	fast gait	0 99	1.08
Max loading B–D	slow gait	0.28	0 40
	fast gait	0.23	0.26
Time of loading A–E	slow gait	0.9	1.01
	fast gait	0 45	0.51
Planimetric evaluation	slow gait	3 7	4.9
	fast gait	0.99	1 08
With a cane			
$\frac{\text{Max loading force}}{\text{Body weight}} = \frac{P}{W}$	slow gait	0.81	0.99
	fast gait	0.91	1 10
Max loading B–D	slow gait	0.53	0.5[illegible]
	fast gait	0.38	0.3[illegible]
Time of loading A–E	slow gait	1.23	1.38
	fast gait	0 7[illegible]	0 8
Planimetric evaluation	slow gait	5 1	6.3
	fast gait	3 1	3.8

The relation of the time B–D of maximal loading

	operated side	non operated side
slow gait	0.4[illegible]9 ± 0.130	0.535 ± 0.150
fast gait	0.374 ± 0.044	0.410 ± 0.055

The relation of the time of loading i.e. distance A–I

	operated side	non operated side
slow gait	0.013 ± 0.243	1.031 ± 0.2[illegible]9
fast gait	0.691 ± 0.039	0.715 ± 0.075

The planimetric evaluation of the complete stance phase curve including *maximal and minimal force points*

	operated side	non-operated side
slow gait	5.77 ± 1.753	6.49 ± 0.336
fast gait	*4.34 ± 0.894*	*4.59 ± 0.274*

COMMENT

The overall results in this investigation confirm the assumption that patients osteotomized for osteoarthritis in the hip joint do not use the operated limb to the same extent as the non operated side. On comparing *measurements of individuals without any apparent joint disease* there is an indication that the results obtained in the non-operated side of this material fall within normal values (*Rydell* 1966). It thus becomes evident that the patients in our study limit the use of the operated hip to a level below what could be expected as normal. As *spontaneous and weight bearing pain have receded according* to the patients' version a natural sequence would be the diminished use of *a* cane postoperatively. As is seen in Table 3 this is, however, not the case and the discomfort which apparently necessitates the aid of *a stick in* walking is obvious in the patient's inability to use his limb to full capacity.

In this context, however, we still feel that the subjective *satisfaction* of each individual patient with the results of the operation is in general so great (Table 4) that intertrochanteric osteotomy is a justified procedure in the surgical management of osteoarthritis of the hip joint as a pain relieving procedure.

Table 3 Walking capacity as related to the use of cane from the follow up 1968

	Before operation	After operation	
		With cane	Without cane
Use of cane	65	55	10
No use of cane	42	25	17

Table 4 Subjective evaluation of postoperative condition at follow up 1968

	Male	Female	Total
Satisfied	38	43	81
Not satisfied	15	6	21
Total	53	49	102

SUMMARY

In a material of 102 patients followed up after osteotomy it was found that more patients than expected had to use a cane permanently when walking. Of 65 patients who had preoperatively used a cane only 10 could discard it after operation Of 42 patients who did not use a cane preoperatively 25 had to use one permanently after operation

This study was carried out to evaluate the weight bearing in the leg operated with osteotomy for hip-osteoarthritis

The tests were carried out on an electronic walk way

The results revealed that all patients limited the use of their operated hip to a level well below normal

The subjective satisfaction of each individual with the operative results nevertheless justifies intertrochanteric osteotomy as a surgical procedure in the management of osteoarthritis of the hip

REFERENCES

Hirsch C. (1960) Intertrochanteric osteotomies in osteoarthritis of the hip *Acta orthop scand* 30 129–136

Hirsch C. & Goldie I (1968) Osteotomy in osteoarthritis of the hip joint. *Acta orthop scand* 39 [illegible]

Lazansky M G (1967) A method for grading hips *J Bone Jt Surg* 49 B 644–657

Rydell N W (1966) *Forces acting on the femoral head prosthesis* Tryckeri AB Litotyp Göteborg

Acta orthop. Scandinav. 40, 346–364, 1969

From the Nuffield Department of Orthopaedic Surgery, University of Oxford and University of Rochester School of Medicine and Dentistry, Rochester, N.Y., U.S.A.

A RADIOGRAPHIC AND CLINICAL SURVEY OF THE HIP JOINT IN SERO-POSITIVE RHEUMATOID ARTHRITIS

ROBERT B. DUTHIE & CARL M. HARRIS

Received 3.II.68

The hip joint in patients with rheumatoid arthritis presents serious difficulties in early diagnosis, in determining the disease pattern of progression and/or remission and in the response to treatment. There are several reasons for this: firstly, because of its anatomical situation several of the earlier diagnostic criteria resulting from soft tissue changes, e.g. synovitis, effusion and increase in local temperature are impossible to determine. Therefore emphasis has to be given to other criteria such as limitation of movement and radiographic changes. Secondly, it is a weight bearing joint affected by biomechanical factors associated with movement and stability, and therefore secondary or coincidental changes of osteoarthritis may arise early and affect the diagnosis, especially in the age group of fifty years which is most commonly seen. And finally, to make a diagnosis of a definite or classical rheumatoid arthritis seven of the American Rheumatism Association criteria (*Ropes et al.* 1949) must be present, but radiographic changes make up only one of these criteria.

Although the incidence and diagnostic criteria of rheumatoid hip joint disease have been described (*Glick et al.* 1963), very few attempts (*Sharp et al.* 1964) have been made to evaluate the hip joint in patients who have definite or classical rheumatoid arthritis as well as a positive serology as shown by the Latex Fixation Test. This reaction is one of the few modalities of rheumatoid arthritis which can be quantitated and most probably delineates a particular type of rheumatoid mani-

---

Presented at the Combined Meeting of the British Orthopaedic Association and the Nordisk Ortopaedisk Forening, London, September 1967.

festation For example *Kellgren* (1964) suggested that hip joint changes in adults with sero positive rheumatoid disease were more likely to be destructive in nature whereas in patients with sero negative disease or with spondylitis the hip changes were those of ankylosis

Therefore the incidence radiographic changes and the functional impairment of the hip joint will be presented in patients not only with definite rheumatoid arthritis but who also exhibited a positive rheumatoid serology Treatment for this particular group of rheumatoid patients will also be mentioned briefly

METHOD

To avoid some of the inevitable selection biases all patients with definite rheumatoid arthritis and positive serology who were seen either as in or out patients in the Arthritis Study Unit of the University of Rochester Medical Center between 1963 and 1964 were studied Eighty four patients including 30 males with "definite" or "classical" rheumatoid arthritis and a positive Latex Fixation Test were included in this study In their selection no consideration was given specifically to complaints regarding hip disease, previous therapy or other medical problems but it is of note that none had had their disease during childhood and all had Latex Fixation titers of 1–40 dilution or greater The Latex Fixation Test was carried out using the method of *Singer & Plot* (1956) with the following modifications the serum to be tested was serially diluted and then heated for 30 minutes at 56 C (Schubart *et al* 1959)

A detailed history of steroid therapy was obtained as well as the presence of hip foot or knee complaints and the greatest disability due to the rheumatoid disease which was present at the time of the examination Passive ranges of abduction adduction flexion extension internal and external rotation were measured. It was important to measure adduction and rotation together in both flexed hips in order not to mask limited motion by pelvic rotation

The functional range of motion was obtained by utilizing Gade s Indices This system was introduced by *Gade* (1947) to assess the active functional range of motion following hip surgery Certain ranges of motion are more important functionally in walking or in climbing stairs etc Therefore these are given more importance and significance by multiplying the ranges of motion by a varying decimal factor A flexion contracture will subtract greatly from the cumulative total when it occurs in the first 90 of flexion but a contracture in other ranges *i e.*, of internal rotation would subtract only slightly Gade s Indices have significance also in giving values not only to the present state of an individual s range of motion but also show more clearly any subsequent change which may occur with progression of the disease or after treatment etc This is particularly important in rheumatoid disease where marked changes in ranges of motion result but the residual ranges are still functional.

Radiographic examination consisted of an antero posterior view of the pelvis taken supine to include both hip joints and lower lumbar spine Lateral radiographs were also taken but did not add significantly to the characteristic diagnostic

changes of rheumatoid disease or its severity Unidentified X rays were examined and charted by one of us without benefit of prior knowledge of history or physical examination The X rays were examined for density of both acetabulum and femoral bones with special regard to osteoporosis and to subchondral sclerosis to joint space as regards narrowing to resorption and or necrosis resulting in changes of the asymmetry in outlines of both the femur and acetabulum and to any protrusio acetabuli or osteophytic formation Attempts were made to observe deformities of adduction around the hip joint as well as the position of the lesser trochanter Previous radiographic films were examined for progression of disease Examinations of peripheral joints were made both clinically and by X ray examination

For purposes of this study radiographic diagnosis of rheumatoid involvement of the hip was made only if there was

(1) Subchondral sclerosis with osteoporosis of the femoral head and the presence of joint space narrowing but minimal new bone formation and/or

(2) Progression of sclerosis or joint space narrowing bone resorption or collapse without osteophyte formation

The X ray diagnosis of rheumatoid hip disease was not made if the following changes were present singly osteoporosis, sclerosis joint narrowing or osteophytic changes However when any of these changes are seen alone in the presence of the rheumatoid factor this is most suggestive of disease and requires treatment These criteria were similar to the standards described by Isdale (19??) Chick (1963) and Forestier (1964)

Data retrieval and analysis was obtained from coded McBee Sort Cards to lessen any bias As in all retrospective studies criticism can be made of the very selection of patients of the choice of the variables to be studied and of the attempt to observe the progress of disease from its first diagnosis The majority of patients began the study with the diagnosis of rheumatoid arthritis and therefore certain bias was early established However such studies do provide worthwhile information about early diagnosis progression and change with the identification of certain disease patterns

RESULTS

It was noted in Table 1 that in the 34 patients having rheumatoid hip disease osteoporosis was present in 27 patients, joint space narrowing in 33 and resorption with collapse in 13 Twenty out of the 34 patients with rheumatoid hip disease had bilateral involvement In this group there were 10 males seven of which had bilateral involvement and 24 females having 13 bilateral hips affected The less frequent appearance of osteophyte formation in the "rheumatoid hip in contrast to that of the non rheumatoid hip (10 such patients) may have resulted from what Ball (1961) has described as a local inhibitory effect by the rheumatoid inflammatory process on reactive new bone formation He has demonstrated in unstable rheumatoid knees gross cartilagenous degeneration without any accompanying marginal lipping or osteophyte formation In the remaining 50 patients which were not considered to

Table 1 Various radiographic features in both patient groups with rheumatoid hips and without involvement of the hips

Changes		Patients with Rheumatoid hip disease	Patients with Non rheumatoid hips
Bone density	Diffuse osteoporosis	27	18
	Subchondral sclerosis	25	6
	Resorption with collapse	13	0
Joint space	Narrowing	33	14
Changes in bony outline	Acetabulum	30	30
	Femur	28	19
Osteophyte formation		16	30
Acetabular deformity	Protrusio	14	0
	Protrusio with femoral head changes	11	0
Static deformity of hips	Adduction	28	19
	Abduction	0	0

Table 2 Distribution of the patient population as regards duration of radiographic follow up

Duration of radiographic evaluation	No of patients	Rheumatoid hip disease	Progression	Resorption and collapse	Protrusio acetabuli
18 months to 4 years	26	10	8	5	3
One X ray	29	6	–	2	2
18 months or less	16	7	7	3	4
4 years to 8 years	10	9	8	2	4
8 years or more	3	2	2	1	1
Totals	84	34	25	13	14

have rheumatoid hip disease there was a great deal of osteophyte formation

In terms of duration of X ray follow up (Table 2) 29 of the patients had only one radiographic examination An additional 16 patients were observed radiographically for 18 months or less It is of interest that in this latter group of 16 patients 7 showed progression of disease indicating the rapidity with which these changes can occur Another feature is that out of the 34 patients who had hip disease 25 showed



Figure 1

Figures 1 2 and 3 A series of radiographs showing the progressive and characteristic appearance of rheumatoid hip joint disease The first radiograph (Figure 1) was taken in 19 ? when the patient was symptomatic with hip pain Figure ? was taken in 1951 when she had become confined to a wheel chair Figure 3 was taken ten years later

progression (Figures 1 2 and 3) Only one patient in the whole series had radiographic and symptomatic improvement but still limitation of movement following immobilization in a Plaster of Paris hip spica for a fracture of the ipsilateral femur (Figures 4 and 5)

Another important radiographic change was the relative frequency of significant osseous resorption of the femoral head (Figure 6) with collapse and compaction in 14 out of the 31 hips involved Resorption on the acetabular side was seen in 11 patients with a protrusio acetabular defect (Figure 7) (This was almost the same number as those hips which showed resorption of the femoral head although not necessarily in the same patient) This suggests that resorption occurs on both sides of the joint and thus pathological change was not limited



Figure 2

only to the femoral head *Johnson* (1964) has described the bony changes in avascular necrosis Firstly there is an apparent increase in bone density because of surrounding osteoporosis secondly a true loss of bone density as seen in bone destruction or subchondral cyst formation and finally a true increase in bone density due to fracture and/or collapse leading to compaction of bone or from new bone formation around trabeculae giving rise to subchondral sclerosis Several of these pathological changes were seen in the rheumatoid hip group of patients but the incidence of frank avascular necrosis as specifically resulting from rheumatoid rather than from degenerative changes was difficult to record when based solely upon radiographic interpretation Also there is no evidence that there is reduced blood supply to the femoral head in rheumatoid arthritis indeed the bone resorption may be due to hyperemia with increased osteoclasis



Figure 3

Table 3 Age distribution in the patient population with 27 out of 34 rheumatoid hip patients being over 50 years of age

Age group	Rheumatoid hip disease	"Non rheumatoid" hips
39 or under	3	6
40–49	4	13
50–59	13	16
60–69	10	12
70 79	4	3
Total	34	50

Age Groups

Over the age of 50 years (Table 3) radiographic evidence of hip joint disease appeared more frequently *i e* 27 out of 34 patients were over 50 years of age This has also been described by *Glick*



Figure 5

Figures 4 and 5 Radiographs demonstrating improvement The first radiograph (Figure 4) was taken in 1960 at the time of an ipsilateral femoral shaft fracture Before this motion was severely limited and the patient was incapacitated by pain The second radiograph (Figure 5) was taken in 1969

Table 4 Distribution of the patient population in terms of duration of symptomatic disease

Duration of symptomatic disease	Rheumatoid hip disease	"Non Rheumatoid" hips
1–4 years	4	21
5–8	13	8
9–12	4	3
13–16	7	4
17–20	1	5
21 years	5	9
Total	34	50



Figure 5

Duration of Symptomatic Disease Correlated with X ray Changes of Hip Arthropathy

It can be seen (Table 4) that the longer the duration of symptoms the more likely there is to be hip joint disease *i e* 4 patients had hip disease with a history of rheumatoid disease of under 4 years duration but 17 out of 34 patients had hip joint involvement with less than 8 years of disease

Fifty patients had no demonstrable rheumatoid radiographic changes in the hip However 21 of these patients (Table 5) had symptoms of hip pain or stiffness a limp a snapping or a feeling of shortening or of restricted movement with inability to pull on stockings etc In the 34 patients who exhibited rheumatoid hip disease only 4 were without symptoms of joint disturbance Three of these were observed by radiographs between 1–6 years and during this time showed progressive



Figure 6 A radiograph of a right hip joint demonstrating marked osseous resorption with minimal new bone formation

Table 5 Showing the radiographic features in 21 patients who did not meet the criteria of rheumatoid hip disease but who were symptomatic in one or both hips

Radiographic features	No of patients
No radiographic changes	3
Osteophytic formation on Acetabulum	4
Osteophytic formation with other changes such as narrowing etc.	8
Sclerosis or narrowing but not together with flexion adduction position	6

narrowing of the joint space suggestive of active disease The fourth had a protrusio lesion with osteophyte formation and narrowing of the joint space



Figure 7 An X ray of the pelvis demonstrating advanced protrusio-acetabuli on the right

Gade's Cumulative Index of Movements of the Hip Joint

On comparing this index with X ray evidence of rheumatoid hip disease (Figure 8) whenever radiographic changes were present there was marked restriction in all movements with significant lowering of the index score in the majority of involved patients (i e 27 out of 34 with less than 85 points A normal hip would be in the 100 110 points range) The strongest correlation occurred between the loss of internal rotation and the presence of radiographic changes (Figure 9) Loss of internal rotation which occurred early was seen to be more affected than any other clinical modality in this series Unlike the movement of internal rotation loss of abduction was less related to severity or to the diagnosis of rheumatoid disease (Figure 10)

Latex Fixation Test

Although 34 patients out of the total patient series of 84 had a significant serological titer there did not appear to be any correlation between the amount of serological titer of the rheumatoid factor to the

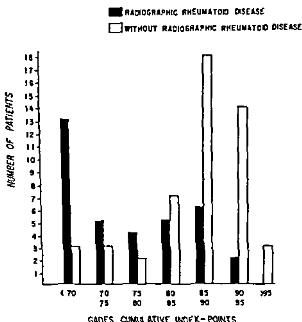


Figure 8 Showing the distribution of the points by Gade's Cumulative Index in the patient population

presence of hip joint disease (In Figure 11) The degree of positivity was not related significantly to the number of patients who had hip involvement but 21 out of the 34 patients who had X ray evidence of rheumatoid hip disease had a positive Latex Test in the medium titer range of 620 or above Glick reported only 29 per cent involvement of one or more hips in 279 consecutive patients with rheumatoid disease but without designating their serological status Positivity in the Latex Fixation Test indicating the presence of a rheumatoid factor is greatest in patients who have had the disease five to ten years (*Alexander* 1964) Its presence may be associated with an increased incidence of hip disease because of the duration of the disease rather than anything more specific

Positional Deformities

The presence of positional abnormality involving the hip articulation was related to losses in certain ranges of movement 28 cases out of 34 rheumatoid hips exhibited an adduction position of the femoral head and neck (Figure 12) and 15 out of these 28 hips showed decreased

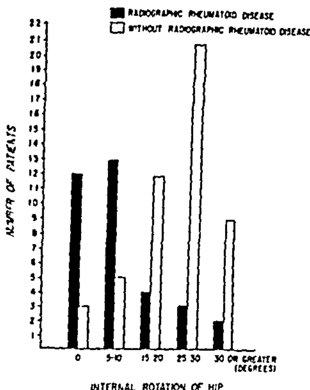


Figure 9 Distribution in terms of degrees of internal rotation of the hip in the two patient groups The figure given is the maximum degree of rotation in the most severely involved hip

abduction of less than 30 on clinical examination Only one had a decreased abduction without any adduction deformity and 5 had normal adduction without this deformity In the remaining 30 patients who were without radiographic rheumatoid hip disease 19 showed a similar adduction deformity In these 19 hips 11 showed osteoporosis 2 sclerosis and 11 joint space narrowing but only as a single feature and without progression However these latter nineteen cases are being followed to see whether they will eventually present joint changes compatible with the diagnosis of rheumatoid arthritis It is difficult to assess the accuracies of static deformities radiographically especially if mild or if there is any variation in the supine position which the patient takes up for the X ray examination or if there is a flexion contracture of the ipsilateral knee present etc *Strange* ([illegible]) has pointed out that in the *flexed osteoarthritic hip which is subluxing slightly* upwards and outwards there is lateral rotation of the head with the

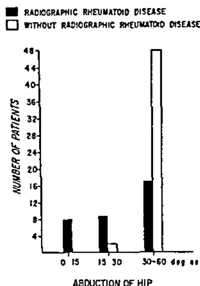


Figure 10 Similar to Figure 9 but showing the degree of abduction and its limitation

lesser trochanter becoming more prominent due to ilio psoas muscle action However in the rheumatoid type of deformity in which the head sinks more deeply into the acetabulum as seen in 14 patients of this survey there was medial rotation with the lesser trochanter becoming less prominent Such changes suggest that the soft tissue pathology may well be contributing to the appearance of this lesion as well as the intra articular changes

Positional deformities have also certain significance particularly in describing the amount of resorption or of alteration of joint space etc However the total mass or surface of the femoral head present on X rays does not appear to be significantly altered by changes in the positions of abduction adduction or rotation (*Isdale*)

Other X ray changes of rheumatoid disease were seen in other joints such as knees and/or feet In all 84 patients there were X ray changes and/or clinical manifestations involving both knees feet or ankles which appeared in the more peripheral form of rheumatoid arthritis

In no case in this series was there bony ankylosis of hip or sacro-iliac disease although this occurred in 2 per cent of the series (*Glick et al*) in which no study of serological status had been carried out

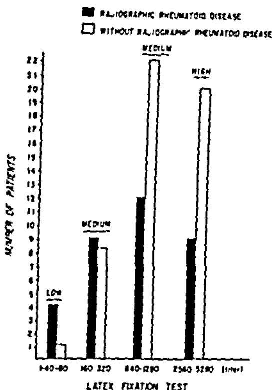


Figure 11 Distribution of the two patient groups in terms of Latex Fixation Test titres

History of Steroid Therapy

In the 31 patients with radiographic rheumatoid hip disease 24 patients had had steroids systemically for varying periods from one year to four years whereas in the 50 patients without radiographic hip disease only 25 patients had had steroids (Figure 13)

In the rheumatoid hip patients who had had steroids 13 showed significant resorption collapse or avascular necrosis It was impossible to correlate the taking of steroids with these changes because much of the data was historical with marked variation in dosage in duration and in type or types of steroid drug given

TREATMENT

The difficulties and poor results of treating rheumatoid hips are obvious but briefly result from firstly the inability to make an early clinical diagnosis or to appreciate the degree and velocity of expected change secondly poor timing of conservative or operative treatment



Figure 12 A radiograph illustrating joint narrowing sclerosis of the femoral heads an early subluxing femoral head on left in abduction

and finally the complexity of other lower extremity joints being involved simultaneously

As regards deciding upon operative treatment there are two main groups of patients *Firstly those patients with structural and permanent change e g resorption with collapse and/or protrusio acetabuli* These require reconstructive/replacement surgery such as a cup arthroplasty or preferably a pseudarthrosis as described by *Girdlestone* (1945) reinforced by an angular trochanteric osteotomy of *Milch* (1950) or of *Batchelor* (1948) Although they relieve pain maintain some stability and improve mobility their results are most variable depending greatly upon the motivation and rehabilitative capacity of each individual patient and whether there is the more than likely progression of the disease in other weight bearing joints

Secondly those patients with pain limitation of motion and radiographic changes of early subchondral sclerosis minimal osteoporosis and joint narrowing These can often be helped temporarily by a soft tissue release of the adductors iliopsoas and occasionally the rectus femoris muscles as well as a partial synovectomy and capsulotomy

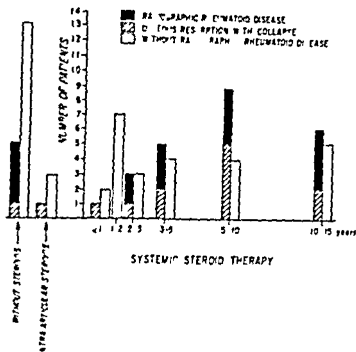


Figure 13 Demonstrating distribution of the two patient groups as well as those with resorption or collapse and their history of the use of systemic or intra-articular steroids

This procedure will provide diagnosis and pathogenesis of this disease. It is followed by traction for 10–14 days, intensive physiotherapy with protected weight bearing for several months within a brace or caliper. This procedure has been carried out in a very small series of ten patients with promising results over short periods of time.

CONCLUSIONS

1 In 84 patients with classical or definite rheumatoid arthritis as well as positive serology, rheumatoid hip disease was diagnosed by radiography in 34 patients (i.e. 40 per cent). Osseous resorption with collapse of the femoral head was seen in 14 patients with a similar number showing a protrusio acetabular deformity.

2 Twenty five of these patients showed progression of the rheumatoid disease with clinical features of pain, limitation of internal rotation and an adductor contracture appearing early.

3 In 27 out of the 34 patients with rheumatoid hip disease there was

a significant lowering of the Gades Cumulative Index particularly in internal rotation and in abduction

4 There was no correlation between the amount of rheumatoid factor by serological titre and the severity of hip joint disease

5 Treatment—on identifying the early "sub-clinical case—prophylactic soft tissue release and synovectomy operation should be carried out to maintain joint integrity

When structural deformation has occurred reconstructive and ablative procedures are necessary

6 24 out of the 34 patients had taken steroids for between 1 and 4 years and of these 13 showed excessive resorption and collapse 25 out of the 50 non rheumatoid hip group had had steroid without resorption or collapse

REFERENCES

1 Alexander W R.M (1964) *Laboratory Aspects of Polyarthritis* Symposium – Polyarthritis. Royal College of Surgeons Edinburgh, Pub 495 T & A Constable Ltd. Edinburgh.

2 Ball J (1964) Radiological Aspects of Rheumatoid Arthritis International Cong Series +61 *Excerpta Med Foundation* p 25–31

3 Batchelor J S (1948) Excision of femoral head and neck for ankylosis and arthritis of hip *Post Grad M J* 24 241–248

4 Forestier J (1964) Radiological Aspects of Rheumatoid Arthritis International Congress Series +61 *Excerpta Med Found* p 295–301

5 Gade Herman (1947) A Contribution to the Surgical Treatment of Osteoarthritis of the Hip Joint. *Acta chir scand* 95 Suppl. 120

6 Girdlestone C R., Watson-Jones R. Stamm T T & Pridie, K. H (1945) Discussion on treatment of unilateral osteoarthritis of hip joint. *Proc Roy Soc Med* 38 363–368

7 Click, E. N Mason R. M & Wenley W P (1963) Rheumatoid Arthritis Affecting the Hip Joint. *Ann Rh Dis* 22 416

8 Isdale I C (1962) Femoral Head Destruction in Rheumatoid Arthritis and Osteoarthritis *Ann Rh Dis* 21 23

9 Johnson L. (1964) *Proceedings of the Conference on Aseptic Necrosis of the Femoral Head* p 33–41

10 Johnson L. (1964) Discussion of a paper *Arthritis and Rheumatism* 7 719

11 Kellgren J H (1964) The Hip Joint International Cong Series +61 *Excerpta Med Found* 301

12 Milch H (1950) Resection angulation operation for arthritis and ankylosis of hip *J Internat Coll Surgeons* 13 750–756

13 Ropes M W Bennett, G A., Cobb S Jacox R. & Jessor R. A (1949) Diagnostic Criteria for Rheumatoid Arthritis *Ann Rh Dis* 18 49

14 Schubart A F Cohen A J & Calkins E. (1959) Latex Fixation in Rheumatoid Arthritis Clinical Significance of a Thermolabile Inhibitor *N E J M* 261 363

15 Sharp J T., Calkins E., Cohen A S., Schubart A F & Calabro J J (1964) Observations on the Clinical Chemical and Serological Manifestations of Rheumatoid Arthritis Based of the Course of 154 Cases. *Medicine* 43 41
16 Singer J M & Plotz C M (1956) The Latex Fixation Test. *Am J Med* 21 888
17 Strange F C St Clair (1965) *The Hip* pp 240 242 Williams & Wilkins Co Baltimore

Acta orthop Scandinav 40 365–372 1969

From the Department of Paediatric Surgery (Head G Pettersson M D) and the
Department of Orthopaedic Surgery (Head C Hirsch M D)
University of Gothenburg Gothenburg Sweden

THE INCIDENCE OF SLIPPED CAPITAL FEMORAL EPIPHYSIS

Björn Henrikson

Received 9 ii 69

Pare (1572) describes separation of the upper femoral epiphysis in this manner Likewise the epiphysis of the head of this bone some times gets loose and separates so that the surgeon is misled estimating that there is a dislocation and not a separation of the epiphysis of the bone in question Here the young surgeon shall notice that the epiphyses of the bones often get loose and separate due to inner or outer causes outer sometimes by the fault of the surgeon who manipulates the tender bones of the small children too rudely or by falling or other causes inner caused by certain fluids which have been floating and rotting in the joint as seen in pox and small pox or by not variolar fluids

Although it has thus long been clear that there can be different causes of epiphyseal separations in the femur it is often impossible to maintain the distinction

This paper therefore deals with slipping epiphyses of the femur irrespective of aetiology

REVIEW OF LITERATURE

Howorth (1966) in an excellent survey has penetrated the literature in the field of slipping epiphysis of the hip but did not present a material

Ferguson & Howorth (1931) *Brogden* (1935) *McAusland* (1935) *Scott* (1936) *Lutken* (1947) *Badgley Isaacson Wolgamot & Miller* (1948) *Ponseti & Barta* (1948) *Heyman* (1949) *Jerre* (1950) *Rüther* (1954) found the proportion of males to vary from 47 4 per cent to 83 3 per cent in materials of 32–423 cases In the larger materials the

15 Sharp J T, Calkins E, Cohen A S, Schubart A F & Calabro J J (1964) Observations on the Clinical Chemical and Serological Manifestations of Rheumatoid Arthritis Based of the Course of 154 Cases. *Medicine* 43 41
16 Singer J M & Plotz C M (1956) The Latex Fixation Test *Am J Med* 21 888
17 Strange F G St Clair (1965) *The Hip* pp 240 242 Williams & Wilkins Co Baltimore

the use of the slender Nyström nail had neither secondary slipping nor epiphyseal necrosis in his series

Both *Wiberg* (1941) and *Billing & Severin* (1959) state that nailing across the epiphyseal cartilage does not cause the zone to close earlier than otherwise

MATERIAL

In Gothenburg a city on the western coast of Sweden capital epiphyseal separations of the femur are treated only in two hospitals The Orthopaedic Clinic of Sahlgren s Hospital and the Department of Paediatric Surgery Children s Hospital. The latter clinic treats patients only to the age of 15 (inclusive) and cases of seemingly obviously traumatic origin have been treated there in the first place The other cases have been treated at the Orthopaedic Clinic.

The period studied 1947–66 (inclusive) included 81 patients 33 of whom had been treated at the Department of Paediatric Surgery and 48 at the Orthopaedic Clinic All those patients who have been sent from hospitals outside Gothenburg have been excluded from this series

30 patients had right sided, 33 had left sided and 18 had bilateral slipping of the epiphysis

The age and sex distribution is clear from Figure 1

The material includes one boy only 3 years old. He was struck by a steam roller and the trauma was thus unusually severe

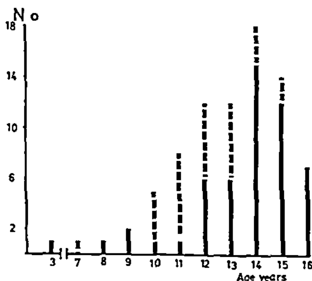


Figure 1 Age and sex distribution of 81 cases of slipped capital epiphysis Age at first admittance is recorded
Girls Interrupted column Boys Solid column

there are differences. The high mean age in Jerre's material is mentioned above. It contains a few patients with an astonishingly high age up to 21 years, which may explain this high mean age. These findings are not in accordance with the closure of the epiphyseal line given by *Rachenstemer (1931)*, which is 18 years for males and 17 for females. Nor is this high age in accordance with *Billings et al* findings about the ossification of the Y-cartilage. It is thus unlikely that all of Jerre's cases have had their age registered at onset of the symptoms.

The preponderance of the left side in one sided cases in this material is in accordance with other materials.

This can be explained by the higher ash weights in bones from the right than from the left extremities found by *Virtama* (1960). A relationship between the strength of bone and its mineral or ash content has been demonstrated by *Vose & Kubala* (1959). *Alffram* (1964) in fractures of the neck of the femur also found the left side to be affected more often than the right one. Left sided injuries are also more common in elbow fractures irrespective of the side of dominance (*Henrikson* 1966).

The incidence of capital epiphyseal separations in the femur can be calculated from Waldenström's figures, as the total population in Sweden at the time of his investigation was 6 142 000. His 30 cases were thus 0.05/10000 of the population or about 0.5/10000 children in the corresponding age group.

Jerre's cases are collected from three hospitals, one in each of three cities in the southern part of Sweden. The total population according to official statistics in the cities at the end of his investigation was 305662 inhabitants. With the same type of calculation it gives 0.5 cases annually/10000 of the children in the corresponding age group.

As the hospitals mentioned treat patients from the countryside around the cities, the population is greater and the incidence correspondingly smaller. Nevertheless the figure is not so far from the one in my own material. In Jerre's investigation the number of cases was increasing in the later years, which he explains as being due to the fact that people formerly did not seek medical advice so often as they do nowadays. An improved diagnosis also among non specialists and a more frequent consultation with orthopaedic surgeons may also have contributed.

As these factors ought to be valid also in Gothenburg, it is very astonishing that the incidence is decreasing for, as stated above, no other hospitals cater to these patients. The traumatic injuries such as

fractures of the elbow have increased significantly in Gothenburg both in absolute and in relative numbers in the same region (*Henrikson* 1966)

A possible explanation is the higher standard of living in the later years with better food for the children

SUMMARY

Out of a population during the period 1947–66 increasing from 333272 to 424473 in Gothenburg the children in the age group 7–16 years amounted to 11–15 per cent and of these 1–7 annually had slipping epiphysis of the hip totally 81 cases

Bilateral slipping occurred in 18 right sided in 30 and left sided in 33 cases Boys were preponderant 53 out of the 81 cases

The mean age at first symptom was in boys 13 5 years in girls 11 8 years and in both sexes together 12 8 years

The incidence varied between 0 2 and 1 3 cases annually/10000 of the population in the corresponding age group and showed a significant decrease especially during the last 5 year period possibly because of better living conditions

REFERENCES

Alffram P A (1964) An Epidemiological Study of Cervical and Trochanteric Fractures of the Femur in an Urban Population *Acta orthop scand* Suppl 65

McAusland A (1935) Separation of the Capital Femoral Epiphysis *J Bone Jt Surg* 17 353–369

Badgley C Isaacson A Wolgamot J & Miller J (1948) Operative Therapy for Slipped Upper Femoral Epiphysis *J Bone Jt Surg* 30 A 19–[illegible]8

Billing L (1954) Roentgen Examination of the Proximal Femur End in Children and Adolescents *Acta Radiol* Suppl 110

Billing L & Severin E (19[illegible]9) Slipping Epiphysis of the Hip *Acta Radiol* Suppl 174

Brogden W (1935) Review of the End Results of fifty seven cases of Slipped Upper Femoral Epiphyses *J Bone Jt Surg* 17 179–183

Camitz H (19[illegible]9) Uber die Behandlung der traumatischen Epiphysenlosung am Caput Femoris *Acta chir scand* 65 82–9[illegible]

Ferguson A & Howorth B (1931) Slipping of the Upper Femoral Epiphysis *J.A.M.A* 97 1867–1872

Henrikson B (1966) Supracondylar Fracture of the Humerus in Children *Acta chir scand* Suppl 369

Heyman C (1949) Treatment of Slipping of Upper Femoral Epiphysis A Study of Results of 4[illegible] cases *Surg Gynec Obstet* 89 559–5[illegible]5

Howorth B (1966) Slipping of the Capital Femoral Epiphysis *Clinical Orthopaedics* 48 10–5[illegible]

Table 1

Osteo arthritis	Vitallium-cup arthroplasty			
	One hip	Both hips	Other side Other method	Total
One hip	14	–	–	14
Both hips	31	2	3	3[illegible]
Total	4[illegible]	[illegible]	3	50

Arthrodesis   Moore prosthesis   Varus osteotomy

Table 2

Age (yr)	Males	Females	Total
≤ 60	2	13	15
61 ≤ 6[illegible]	7	13	[illegible]0
≥ 6[illegible]	[illegible]	15	17
Total	11	41	5[illegible]

1960 and 196[illegible]. Fourteen patients with unilateral arthrosis and 31 with bilateral arthrosis were operated upon on one side and two were operated upon on both sides. Three patients were operated with arthroplasty on one side and some other form of operation of the hip on the other (Table 1). Thus all together 5[illegible] patients were subjected to operation but 3 had died from intercurrent diseases not related to the hip operation and one had left Sweden and was thus untraceable. So forty eight patients submitted to [illegible]0 arthroplasties were after-examined by the author. The longest interval between the operation and the review was 6 years and the short[illegible] 9 months (average 25 months). It is clear from Table 2 that women were almost 4 times as common as men (41 11) and that most of the patients were above 60 years of age.

INDICATIONS AND OPERATIVE TECHNIQUE

The main indications for operation were pain on weight bearing, pain at rest and obligatory use of a cane when walking. Moreover in most of the patients osteotomy had been considered [illegible] because of the limited rang[illegible] ion or because of marked contractur[illegible] other patients arthrod[illegible] en considered contraindicated becau[illegible] age or back pain (9) [illegible] nt's refusal. In addition most of [illegible] had bilateral arthrosis.

The operation was p[illegible] ly by the technique d[illegible] neth Petersen



Figure 1 a) Preoperative coxarthrosis Observe tendency to subluxation b) Postoperatively Observe shaping of acetabulum

(17 18) To avoid bone new formation the gluteal musculature was loosened by sharp dissection supraperiostally from the outer surface of ala ossis ilii (4 6) In some cases the musculature was partly loosened also from the inner surface of the ala in order to get better access to the joint In two cases iliopsoas tenotomy was done because of severe contractures In 20 cases the capsule was extirpated but in 30 it was preserved and sutured at the end of the operation The surgical luxation of the head sometimes though only seldom required small cheilectomy of the anterior acetabulum The acetabulum was then drilled and care being taken to chisel the socket to adequate depth (12) and to remove all cartilage and sclerotic bone down to a healthy bleeding bony surface The head was prepared in the same meticulous way Cystic cavities were sometimes filled with bone chips from the crest The vitallium cup was afterwards fitted in such a way that it could articulate with both the caput and the acetabulum Attempts were made to get the depth of the cup such as to leave about 0 5 cm of the edge of the cup outside the acetabulum rim and the cup in a normal valgus position (8) See Figures 1 a–b

Postoperative care consisted of 4 weeks rest in bed the first 2 weeks with the legs held in abduction by a plough like support and in a few cases with inward rotation traction to prevent luxation After 2 weeks all the appliances were removed and the patient began to exercise abduction and adduction with the heels on roller skates against an increasingly *inclined plane* Four weeks *after* the operation the patient was allowed to get up and systematic physiotherapy was started including walking with canes All patients spent at least 6 weeks in hospital (average 10 weeks) In 10 cases physiotherapy was continued at the outpatient department

Complications Delayed healing of the skin without infection occurred in 2 cases thrombosis in 2 pneumonia in 2 and osteitis of the crest in one All together 14 per cent had postoperative complications which however never appreciably prolonged hospitalisation or caused permanent sequelae Neither did luxation ever occur In 2 cases where the cutaneous lateral femoral nerve had obviously grown in the operation scar meralgia paraesthetica appeared as a late complication

RESULTS

In forty three (86 per cent) of the hips reported patients said that they were satisfied with the operation. Another 5 were content with some reservations, 2 because the good result did not appear until 3 years after the operation, 2 because they still had pain on weight bearing and 1 because the range of motion was smaller than before the operation though the hip was painless. Only 2 patients were dissatisfied with the therapy because the symptoms were practically the same as before operation. In these 2 patients treatment must be regarded as unsuccessful. For the sake of simplicity the indexes devised by *Cade and Shephard* (6, 13) are used in the further description of the results.

According to this calculated pain index the result was good in 86 per cent of the operations, thus the same number as were satisfied with the treatment. In 14 per cent the hips were fairly painless and in no case was the result poor, thus not even in the 2 who were dissatisfied with the operation.

Table 3

Excellent	54%
Good	32%
Fair	14%
Poor	0%

Pain (Index according to Cade)

By partial analysis of the figures given in Table 3, 12 per cent were completely relieved of pain both in weight bearing and during rest, 31 per cent had negligible pain in weight bearing and 2 per cent had only pain during rest but not sufficient to disturb sleep. 22 per cent had persistent but often milder pain in both weight bearing and during rest.

Table 4

Mild	14%
Moderate	62%
Severe	24%

Restriction of functional activity (Index of Cade)

Functionability, i.e. ability to manage the activity of daily living, is given in Table 4. There was little or no impairment in 14 per cent, moderate impairment in 62 per cent, while 24 per cent still did not manage themselves properly. Analysis of the functions of the above index showed that 31 patients could put on their socks and shoes with

out difficulty and 47 could manage stairs properly—activities which none of the patients could manage before the operation All the patients walked with some limp but 8 did not use any cane while 18 needed one cane 21 patients used two canes most of them with severe un treated arthrosis also of the other hip One patient was chair ridden because of destruction of the other hip after sepsis

Table 5

None	36 %
Clerical	8 %
Housework	54 %
Industrial	2 %

Working ability

Another partial function included in the index showed in Table 4 is working capacity 54 per cent could manage household work a figure which is influenced by the fact that most of the patients operated upon were women most of them house wives 8 per cent had returned to previous sedentary occupations while only 2 per cent (one patient) had returned to industrial work and none to heavy work 36 per cent were not able to work but they could largely manage the daily activity of taking care of themselves In the evaluation of the number of retired patients it should be borne in mind that all except one were above 60 years of age

Before the operation there were severe flexion contractures in 27 hips compared with only 4 at the after-examination Considerable outward malrotation had been noted in 25 patients before treatment compared with 13 at the after-examination To reduce the postoperative severity of such malrotation the surgical technique has been somewhat modi fied instead of chiseling out the acetabulum cranially centrally at tempts are made to chisel it out backwardly upwardly and the primary results in this respect appear promising Before the operation 17 hips showed considerable abduction and adduction contractures At the after-examination time these abnormalities persisted in 6 but were much less than before the operation The mobility index according to Gade is given in Table 6 where all movements are included Before the operation 10 hips had poor mobility against 2 at the time of after examination The preoperative mobility in another 10 was moderate and somewhat better after operation in 4 of them Good mobility was noted before the operation in 30 cases compared with 42 at the after examination

Table 6

Before operation	After operation Excellent	Good	Fair	Poor	Total
Excellent	5	0	0	0	5
Good	7	16	2	0	25
Fair	0	10	0	0	10
Poor	2	2	4	2	10
Total	14	28	6	2	50

Mobility (In index of Gade)

The mobility had thus increased but one should not expect the operation to improve the mobility so very much (11). The mean Gade index was 24 before the operation and 39 at the after-examination thus an increase by 15 units which is statistically significant. However this increase of the mobility of the hip does not mean that the range of motion was anything like normal but it does mean a functional improvement enabling the patient better to manage the activities of daily living.

Roentgenologically the acetabulum had migrated towards the lamina interna in 10 per cent and some shortening of the neck was seen in 12 per cent. These figures showed no correlation with the interval between the operation and the after-examination. Despite loosening of the gluteus musculature outside the periosteum bone new formation occurred in 7 cases. But it was always a question of small exostoses from the ala and in no instance of deposits situated close to the joint and thereby reducing the range of movement. In none of the patients had myositis ossificans occurred.

SUMMARY

From the Department of Orthopaedic Surgery in Härnösand fifty hips subjected to arthroplasty with the vitallium cup were reviewed and the results described. The mean interval between the operation and the after-examination was 25 months. The patients were 63 years old as an average.

86 per cent were satisfied with the operation and an equally large percentage were practically free of pain. Functionally the results were good in 14 per cent and fairly good in 62 per cent. On the other hand working capacity was not so good but 64 per cent were at work, mostly women in householding work.

A certain increase of mobility was achieved but not so large as had originally been expected of the operation

Migration of the acetabulum occurred in 10 per cent and some resorption of the neck in 12 per cent

Before the operation all the patients had had severe disabling arthrosis often bilaterally and most of them were old The results were nevertheless relatively good and show that the reported method still has a place in the surgery of the hip

RESUME

50 hanches operees a la Clinique orthopedique de Harnosand ont eté reexaminées et il est rendu compte des resultats constates La duree d observation a ete en moyenne de 25 mois et l age des malades est en moyenne de 63 ans

86 pour cent satisfaits des resultats de l operation et un pourcentage semblable des malades sont sans douleur Au point de vue fonctionnel on constate un bon resultat dans 14 pour cent et un resultat relativement bon dans 62 pour cent des cas En revanche la capacite de travail chez les malades n est pas aussi elevee 64 pour cent toutefois capables de travailler la plupart des femmes dans leur foyer Une augmentation de la mobilite a eté obtenue mais a moindre degre que cells que l on escomptait au debut Il y a eu un glissement de la tete dans 10 pour cent des cas et une certaine resorption du col dans 12 pour cent

Tous les malades operes et reexaminés presentaient avant l intervention chirurgicale des arthroses graves prononcees souvent bilaterales et etaient le plus souvent des personnes agees Malgre cela les resultats sont relativement bons et montrent en quelque sorte la position de cette méthode opératoire dans la chirurgie de la hanche

ZUSAMMENFASSUNG

50 an der orthopedischen Klinik in Warnosund operierte Huften wur den nachuntersucht und das Ergebnis wird vorgelegt Die Beobachtungszeit war durchschnittlich 25 Monate und das Durchschnittsalter der Patienten war 63 Jahre

86 Prozent sind mit der Operation zufrieden und ein ebensogrosser Prozentsatz is so zu sagen schmerzfrei Funktionell findet man ein gutes Ergebnis in 14 Prozent und ein ziehmlich gutes in 62 Prozent Dagegen ist die Arbeitsfahigkeit der Patienten nicht so hoch aber 64

Prozent sind jedenfalls arbeitstüchtig. Die meisten sind Frauen mit Hausarbeit. Eine gewisse Zunahme der Beweglichkeit wurde erreicht, jedoch in einem geringeren Ausmasse als man sich anfänglich von der Operation erhoffte. Pfannenwanderung liegt in 10 Prozent vor und eine gewisse Collumresorption in 12 Prozent.

Sämtliche operierten und nachuntersuchten Fälle hatten vor der Operation ausgesprochene, schwere Arthrosen, oft bilateral und es drehte sich zumeist um alte Patienten. Trotzdem findet man ein relativ gutes Resultat, das Platz der Operationsmethode innerhalb der Hüftchirurgie gut aufrechterhält.

REFERENCES

1. Alvik, Ivar (1950) Arthroplasty of the hip joint ad modum Smith-Petersen. *Acta orthop. scand.* 20, 78–93.
2. Aufranc, Otto (1957) A report on 1000 cases of arthroplasty of the hip over a fifteen-year period. *J. Bone Jt Surg.* 39-A, 237–248.
3. Bickel, William (1948) Cup arthroplasty of the hip. *J. Bone Jt Surg.* 30-A, 647–656.
4. Denham, R. A. & Law, W. Alexander (1957) Arthroplasty of the hip. *J. Bone Jt Surg.* 39-B, 614–692.
5. Emmel, Harry L. et al. (1957) End result study of vitallium-cup arthroplasties of the hip from Seattle Orthopaedic and Fracture Clinic. *J. Bone Jt Surg.* 39-A, 451.
6. Caile, H. (1947) Surgical treatment of osteo-arthritis of the hip joint. *Acta chir. scand.* 95, Suppl. 120.
7. Hammond, C. et al. (1954) Vitallium mold arthroplasty of the hip. An end result study. *J. Bone Jt Surg.* 36-A, 1298.
8. Law, W. Alexander (1962) Late results in vitallium mold arthroplasty of the hip. *J. Bone Jt Surg.* 44-A, 1497–1517.
9. Lindström, Nils G. (1950) Arthroplasty and arthrodesis in arthrosis deformans coxae. *Acta orthop. scand.* 20, 212–243.
10. Gibson, Alexander (1949) Vitallium-cup arthroplasty of the hip joints. *J. Bone Jt Surg.* 31-A, 861–868.
11. Ramadier, J. O. & Levitan, C. (1956) L'Arthroplastie à cupule. Expérience de 117 cas. *Rev. Chir. Orthop.* 42, 29–43.
12. Semb, C., Jakobsen, A. & Dahl, H. K. (1961) Fourteen years experience with Smith-Petersen's arthroplasty. *Acta orthop. scand.* 31, 216–217.
13. Shephard, M. (1954) Assessment of function after arthroplasty of the hip. *J. Bone Jt Surg.* 36-B, 354–363.
14. Shephard, M. (1960) A further review of the results of operations on the hip joint. *J. Bone Jt Surg.* 42-B, 177–204.
15. Smith-Petersen, M. N. (1939) Arthroplasty of the hip. *J. Bone Jt Surg.* 21, 269–288.
16. Smith-Petersen, M. N. (1948) Evolution of mould arthroplasty of the hip joint. *J. Bone Jt Surg.* 30-B, 59–75.

17 Smith Petersen M N (1949) Approach to and exposure of the hip joint for mold arthroplasty *J Bone Jt Surg* 31 A 40–46
18 Smith Petersen M N (1952) Lessons learned from fourteen years experience with mold arthroplasty of the hip joint *J Bone Jt Surg* 34 B 714
19 Stinchfield Frank & Carroll Robert (1949) Vitallium cup arthroplasty of the hip joint. *J Bone Jt Surg* 31 A 628–638
20 Tillberg Bengt (1969) Intertrochanteric valgus osteotomies by coxarthoses *Acta orthop scand* To be published
21 Witvoet, J (1963) Les resultats des arthroplasties à cupule en vitallium dans le traitement de la coxarthrose essentielle *Rev Chir Orthop* 49 794

Acta orthop. Scandinav. 40, 382–391, 1969

From the Department of Orthopaedic Surgery (Head: Prof. Carl Hirsch, M.D.)
Sahlgrenska Sjukhuset, University of Göteborg, Sweden

THERMOGRAPHIC EVALUATION OF RESULTS OF SYNOVECTOMY IN RHEUMATOID KNEE JOINTS

IAN GOLDIE

Received [illegible].1.69

INTRODUCTION

Every object with a temperature above absolute zero radiates from its surface electromagnetic waves. These appear within the infra-red sector of the spectrum. This self-emitted energy can be collected optically and transformed into proportional electrical impulses. In turn these can be converted into visible light to form a picture, a so-called thermogram (*Lawson* 1957). A thermogram is thus a pictorial representation of the temperature contours of an observed surface. Its reproduction does not require any external illumination nor irradiation of the object which may be human or otherwise. It can therefore be made in complete darkness and does not depend on skin colour or pigmentation but relies to a certain degree on the temperature of the skin (*Barnes* & *Gershon-Cohen* 1963). This is in contrast to infra-red photography which depends upon the reflection of waves from the surface of the object which has to be irradiated with short wave-length infra-red from an extraneous source (*Barnes* 1963).

The waves radiated by the human body by virtue of its temperature are from 3 to 20 microns and within these limits the human skin is essentially nonreflective and nontransparent. According to certain basic laws of physics it thus acts as a perfect emitter of infra-red energy (*Hardy* 1939).

For the last ten years these properties have been utilised in medicine. In 1956 Lawson demonstrated that certain cancers of the breast were associated with a rise in the overlying skin temperature. He produced heatpictures demonstrating graphically the temperatures he had noted

with a thermocouple The new technique was called thermography The pictorial registration of biologic dynamic events has become greatly facilitated since by the introduction of accurate and easy handled infra red cameras

In short the working concept of a thermograph is that it attracts the emitted heat rays the vertical of which are transferred via a plane mirror and the horizontal by a rotating prism to a photoconductive detector of indium antimonide The sensitivity of this is increased by cooling it with liquid nitrogen The detector signal is then fed to a display unit where a television like picture is obtained on a screen This picture can be adjusted for contrast (temperature range) and brightness (temperature level) by controls on the display unit It thus becomes possible to model out the pictorial registration of the emitted heat and temperature differences down to 0 2 C can be revealed (*Bjork* 1967)

The practical value of thermography in clinical medicine appears to be dependent on conditions which give an increase in local tissue tem peratures and inflammatory states seem to be ideal for this (*Brane mark* 1967) The rise of temperature of affected joints in rheumatoid arthritis provides a useful measure of the activity of the disease With infra red thermography it has proved possible to follow the progress of the disease and the influence drug therapy may have (*Boas* 1964 *Cosh & Ring* 1967 *Lloyd Williams* 1967) As yet no reports have dealt with the thermographic assessment of rheumatoid joints subjected to surgical treatment involving removal of synovial tissues

The purpose of this study has been to evaluate the results of syno vectomy in rheumatoid knee joints by employing thermography as an objective instrument of registration

MATERIAL AND METHODS

Patients with rheumatoid arthritis fulfilling the requirements of the American Rheumatism Association were selected (*Ropes et al* 1958) Only kneejoints were studied as these more easily lend themselves to other objective supplementary evaluation metho ls like intra articular temperature measurements radiology and pathomorphologic and biochemical investigations which by comparison facilitate and make the interpretation of thermograms more reliable Patients with swollen periarticular tissues and articular exsudates were preferred for synovectomy The radiologic appearance of the joint structures varied but did not limit the indications for synovectomy No gre ter deformiti s were present All j ints were stal le and all patients were mobile though with differing degree of activity prior to surgery

In all 25 patients representing 27 kneejoints were operated

The synovectomy was in all cases performed through two parapatellar incisions. The synovium of the medial and lateral compartments and of the suprapatellar bursa was removed. The Hoffa fat pad was left intact. In cases with destroyed semilunar cartilages the remnants were excised. Synovial granulations around the cruciate ligaments were cut away. The synovium of the posterior region of the capsule was left. Destructions in the bone-cartilage zone were smoothed off and osteophytes chiselled away. Great care was taken to remove all pathologic tissue from the bone cartilage zone. The fibrous capsule was sutured with silk and suction drainage was applied for approximately 24 hours. The operations were done under a tourniquet. Mobilisation was instituted immediately after operation and the patient was permitted to move freely around with weight bearing as soon as there was relief in the postoperative pain.

Thermograms were made before operation and at regular intervals postoperatively as a rule after 6 weeks, 3 months (at which time the synovial tissue has regenerated, *Stevens & Whitefield 1966, Marmor 1967, Goldie 1968*), 6 months, one and two years. In the earlier stages of this work a thermograph from FOA (Försvarets forskningsanstalt) was used but later an AGA Thermovision which permits plotting of isotherms.

Simultaneously skin temperatures were recorded by directly applied thermocouples.

RESULTS

In all instances the same type of emission pattern was registered. The region corresponding to the synovial distribution showed prior to surgery an emissivity which was largely increased as compared to that of the surrounding tissues. As a rule the topography of the joint capsule could easily be outlined by the sharp border demarcating the area of increased heat emission. Within this region variations were seldom seen but it could occur that the area corresponding to the Hoffa fat pad stood out more intensely. This was especially noticed after synovectomy when the intensity in synovial emissivity was lowered.

Six weeks following synovectomy no changes were registered in the thermograms. This was believed to be due to a prolonged postoperative reaction possibly because of reactive hypervascularisation during the initial stages of synovial regeneration.

At three months a marked reduction in emissivity was registered in all cases but there was still considerable heat being emitted especially in the zones of incision which again was interpreted as hypervascularisation representing a normal constituent of wound healing.

At six months and one year—a considerable time after full regeneration of synovial tissue—the heat emissions fell within normal limits.

Two illustrative cases have been selected to demonstrate that which has been recorded all along this series.



Figure 1 Knees of patient as case no 1 After synovectomy The upper knee is the right from the medial aspect the lower the left from the lateral

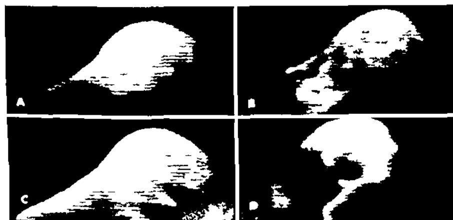


Figure 2 a Thermogram preoperatively of outside of left knee Even distribution of heat emission within limits of synovial lining of the joint

b Inside of left knee at sam time as a) Increased em ssion is noticed within the joint but especially around the patellar region which is a common phenomenon

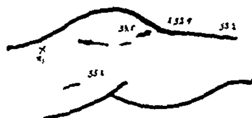
c Preoperative thermogram of inside right knee

d Outside of right knee at same time as c) The oblique streak of increased emis sion in the lower part of the f eld is from a subcutaneous vein

Case 1

A 6? year-old male previousl healthy but with rheumatoid arthritis since 19 9 Admitted for a t ular oft tissue urgery in 1964 Most joints were invol ed but the patient uff red mostly from hi knees ith a certain prefe ence f r his left which was o ted with a near tot l synovectomy after a lmission The patient s knees are e i in F gure 1 after ynove tomy There is a slight extension defect which is m re marked in the r ght knee The preoperative the mograms (F gures

Figure 3a Result of direct measurement of skintemperature of left knee in case no 1 at the same time as the preoperative thermogram was made The figures indicate the temperatures in Centigrade





b Same as a) but right knee

Figure 4 Thermogram of left knee in case no 1 eight months after synovectomy Heat emission above normal but lower than preoperatively Concentration of heat to Hoffa fat pad and patellar region which is a common finding





Figure 5 Thermogram of outside of right knee in case no 1 five months after synovectomy There is a marked decrease but serpentine emission pattern belongs to veins



Figure 8 Thermogram of both knees prior to synovectomy in case no 2 Increased pletely normal emission with modelling out of surrounding areas
b Inside of same as a) Here the modelling has been centred on the tibial tuberosity which normally is a hot spot
c Inside of right knee one year after synovectomy There still rema ns some in creased heat emission around the Hoffa fat pad which is regarded as normal Oblique streaks of emission represent veins
d Outside of same as c) As compared to Figure 5 the lecrease in em ssion is noticeable

2 a, b c d) show intense heat emission well localised to the expansion of the synovial tissue. Strangely enough the emission is stronger from the right knee which clinically was better than the left. In order to discern how much heat emanated from subcutaneous tissues as compared to what the overlying skin might give off direct skin temperature read ngs were made at the same time with the values as seen in Figures 3 a b These fall within normal estimates The part played by the skin as a heat emitter was therefore regarded as nil The patient was discharged after ten days fully weightbearing without other pain than postoperative discomfort Subsequent thermograms showed a slow regress and at a new admission for synovectomy of the right knee eight months after the first surgical intervention in the left knee the thermo ram of this appeared as is seen in Figure 4 There is till some heat em s ion but markedly decre sed and now more localised to the patellar region and the Hoffa fat pad The right knee was operated with a near total synovectomy and prior to this a thermogram displa ed the same he t emis sion as seen in I gures ? c and d. A thermogram of the right knee five months postoperativel is seen in Figure 5 There is still an increased emis i n as com pare l to surrounding tissues but decreased in comparison to the original thermo

Figure 7 Knees of patient no 2 one year after synovectomy





Figure 8 Thermogram of both knees prior to synovectomy in case no 9 Increased emission especially around the medial aspects where as a rule the swollen knee is most bulgy and has the most affluent synovium

gram (Figures 2 c and d) The left knee at 20 months post operatively shows absolutely normal conditions (Figures 6 a and b) and the one year control of the right knee (Figures 6 c and d) shows a further decrease with almost normal emission Clinically the patient has shown a steady improvement as regards his knee condition

Case 9

A 47 year old previously healthy male with rheumatoid arthritis since 1956 All joints involved but especially the knee joints In January 1965 synovectomy was performed in the left knee and in March of the same year the right knee was proceeded with Figure 7 shows the appearance of the operated knees one year after



Figure 9 Thermogram of case no 2 one year after synovectomy There is now normal emission which can be visualised by the difficulty in scanning this area free from the emission of the surrounding tissues

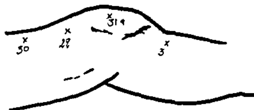


Figure 10 Direct skin temperature measurement in case no 2 at time of first synovectomy Temperatures in Centigrade

the second operation and in Figures 8 and 9 the thermograms preoperatively and one year postoperatively are reproduced The tissues around the joint now emit more heat than the joint itself Skintemperature recordings at the time of the first synovectomy are seen in Figure 10 and prepresent normal values The patient who has been wheelchair bound for more than two years now freely moves around

COMMENT

In this investigation it has become evident that infra red thermography is a useful supplementary tool in the recording of the therapeutic effect of synovectomy in rheumatoid arthritis The evaluation by this method which is objective and non touch—thus without extraneous interference which often accompanies many registration methods—is of value as other reliable and comparable parameters are difficult to obtain More over it presents detailed information over a large area in contrast to that received by point sources Another advantage is the sensitivity of

the registration device in its prompt depiction of biologic dynamic events as e g reaction of an inflammatory condition to anti inflammatory drugs (*Cosh & Ring* 1967) or vascular response to vasoactive substances (*Brånemark* 1967)

The advantages thus combined with the use of this method are entirely dependent on the heat emitted from the surface of the scanned object In this study it has been taken for granted that the emitted heat is secondary to the vascular state of the synovial tissues and the question arises if nearby structures like bone muscles and overlying skin may add or subtract to the appearance of the final thermogram

Body temperature as a rule is well controlled to about 37° C The skin however which normally is of a lower temperature than that of the body exhibits thermal fluctuations dependent on its environment Extraneous heat or cold sources have been thought to cause changes in skintemperature (*Barnes* 1963) But normal human skin is a most suitable emittor in the long wave length infra red and it is impossible to make it appear hotter by applying foreign substances It should however be pointed out that fat acts as a good insulator excepting those instances where there is rich vascularity as in the Hoffa fat pad As a rule regions containing fatty areas do not appear in the thermogram and consequently are regarded as cold spots Other factors which have a heat effect are thermal conduction from heat sources within the body vascular activity within and below the skin surface, propagation of caloric energy in form of heat loss by respiration and metabolic tissue events These may all influence the thermogram but they can be minimized by making the study with the subjects in an air conditioned room with a low temperature and after a period of adjustment to optimal thermal conditions With such precautions the thermogram becomes a true thermal topogram of the surface of the body and the contrasts obtained arise largely from the heat conducted to the skin over the corporal regions registered

This study has been performed taking all abovementioned precautions into consideration The skin temperatures were measured and disclosed normal values Therefore the thermograms of the rheumatoid kneejoints have been regarded as the final result of deep and superficial circulatory mechanisms and of tissue metabolism in the affected areas The changes observed in the postoperative thermograms have been ascribed to the surgical removal of tissues the site of these circulatory and metabolic disturbances

SUMMARY

Synovectomy has been performed in 25 patients representing 27 knee joints All patients had rheumatoid arthritis as classified by the American Rheumatism Association An objective way of registering the postoperative course was found in the use of thermography a pictorial scanning system of the heat which is emitted from the body surface

Repeated postoperative thermograms showed that in all patients a decrease in heat emission followed synovectomy This is interpreted as an amelioration of the inflammatory state of the joint Clinically an improvement followed which paralleled the lessened intensity of heat emission

REFERENCES

Albert S M & Glickman M N (1964) Thermography in Orthopaedics *Ann N Y Acad Med* 121 157-170

Barnes R. B (1963) Thermography of the Human Body *Science* 140 8 0-8,7

Barnes R. B & Gerschon Cohen J (1963) Clinical Thermography J A M A 185 949-95?

Boas N F (1964) Thermography in Rheumatoid Arthritis *Ann N Y Acad Med* 121 ??3-234

Björk, N A (1967) AGA Thermovision a high speed infrared camera with instantaneous picture display *Journ de Rad* 48 30-33

Brånemark, P I (1967) Biologic and Clinical Evaluation of Infrared Thermography *Journ de Rad* 48 69-76

Cosl, J A. & Ring E. F J (1967) Techniques of heat detection used in the assessment of rheumatic diseases *Journ de Rad* 48, 84-89

Goldie I., in cooperation with Brånemark P I (author) (1965) Infrarodtermografi Medicinsk anvandning av varmebildsteknik. Spectrum International, No 2 Pfizer AB Sweden

Goldie, I Yet unpublished data

Hardy J D (1939) The radiating power of human skin in the infrared. *Am. J Phys* 127 454-462

Lawson R. N (195?) Implications of surface temperatures in the diagnosis of breast cancer *Canad Med Ass J* ?5 309-310

Lloyd Williams K. (1965) Pictorial heat scanning in medicine *Documenta Geigy*

Lloyd Williams K. (1967) Mesomorphic cholesterol crystals in surface temperature measurement. *Journ de Rad* 48 68-69

Marmor L. (1967) Surgery of Rheumatoid Arthritis H. Kimpton London

Ropes M. W., Bennet, G A., Cobb S., Jacox R. F Jesser R. A (1958) Revision of diagnostic criteria for rheumatoid arthritis. *Bull on Rheumat c Diseases* 9 (no 4)

Stevens, T & Whitefield G A. (19?) Synovectomy of the knee in rheumatoid arthritis *Anal Rheum Dis* ?5 ?0-?2

For further and more detailed information about thermography in clinical practice see Thermography and its Clinical Applications which is a monograph and registered as vol. 121 [illegible] 1 O t. 9 1964 (304 p) of the New York Academy of Sciences

Acta orthop. Scandinav. 40, 392–401, 1969

From the Department of Orthopaedic Surgery (Chief: Professor Carl Hirsch), University of Göteborg, Sweden

UNUSUAL GANGLION CYSTS IN THE NEIGHBOURHOOD OF THE KNEE JOINT

A Report of Six Cases–Three with Involvement of the Peroneal Nerve

BERTIL STENER

Received 13.1.68

Ganglion cysts in the neighbourhood of the knee joint do not generally cause any diagnostic difficulties. Problems may, however, sometimes arise because of signs or symptoms that mislead the examiner so that the true nature of the lesion is not realized. This will be illustrated here by the description of six cases observed in our clinic from July 1965 to June 1967. Two patients referred for a suspected primary muscle tumour had a ganglion with its major part located intramuscularly; in one patient a subcutaneous parapatellar tumour proved to be due to a ganglion cyst of the lateral meniscus extruding between the patellar tendon and the ilio-tibial tract; in one patient in whom a prolapse of an intervertebral disk had been suspected the symptoms were found to be caused by a ganglion cyst of the lateral meniscus exerting pressure on the peroneal nerve; and in two patients with the clinical diagnosis of a Schwannoma of the peroneal nerve the operation revealed an intraneural ganglion.

Case 1

A 54-year-old man was referred for a suspected muscle tumour. For several months he had noticed a swelling on the outside of the left calf. At examination a firm mass more than 10 cm long was palpated lateral to the fibula. Angiography showed no pathological vessels. The mass seemed to fluctuate and at operation it proved to be a ganglion situated in the peroneus longus muscle. The surgical specimen with the ganglion surrounded by a thin layer of muscle is shown in Figure 1.



Figure 1 Case 1 Intramuscular ganglion in the peroneus longus The ganglion has been removed together with a thin layer of surrounding muscle tissue. Actual size

The proximal end of the ganglion was in close relation to the proximal tibio fibular joint.

Case 2

A 23 year-old woman was referred for a suspected muscle tumour For a month or two she had noticed a slowly growing lump in the distal antero-lateral part of the left thigh. A round, firm mass the size of a plum was palpated at examination It proved to be fixed if the quadriceps was contracted and mobile if the thigh muscles were relaxed. Angiography showed that vessels were rather scarce at the site of the mass. At operation a cystic tumour was found in the vastus lateralis (Figure 2) A thin extension of the cyst reached almost to the patella along the

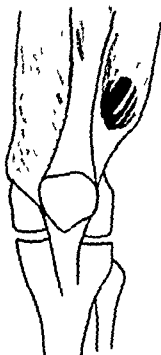


Figure 2 Case 2 Intramuscular ganglion in the vastus lateralis A thin pedicle of the ganglion extends into the tendon of the muscle

tendon of the muscle The content of the cyst was clear and gelatinous and histological examination showed the characteristic picture of a ganglion

COMMENT

In both these cases the ganglion had an intramuscular location and was so far from the knee joint that the correct diagnosis did not present itself both patients were referred for a suspected primary muscle tumour

Case 3

A 40 year old man had for about six months noticed a slowly growing lump distal and lateral to the left patella (Figure 3) He had not experienced any trauma and had no discomfort in the knee joint The lump felt firm and became less mobile and more prominent during contraction of the quadriceps Operation disclosed a large ganglion cyst of the lateral meniscus extruding subcutaneously The ganglion emanated from the anterior part of the ruptured meniscus (Figure 4) and largely occupied the site of the infrapatellar fat pad The clinically observed, subcutaneous part of the ganglion was continuous with the larger deeper part via a flattened rather narrow portion (between arrows in Figure 4) located in the natural gap between the patellar tendon and the ilio tibial tract



Figure 3 Case 3 Subcutaneous tumour lateral to the apex of the patella of the left knee joint



Figure 4 Case 3 Large multilocular ganglion cyst of a ruptured lateral meniscus Between arrows the isthmus connecting the subcutaneous part of the ganglion (cf Figure 3) with the major more deeply located part

COMMENT

It is unusual for a ganglion cyst of the lateral meniscus to emerge subcutaneously between the patellar tendon and the ilio tibial tract This phenomenon was observed in several of the 281 cases of ganglion cyst of the lateral meniscus reported by *Smillie* (1962) In the present case it is remarkable that the patient experienced no discomfort at all in the knee joint in spite of the large size of the ganglion and the ruptured meniscus It was the growing subcutaneous lump which caused him to seek medical advice

Case 4

A 40 year old man was referred for a suspected prolapse of an intervertebral disk. The records by other examiners indicated that an L5 syndrome had been diagnosed three years earlier and that this diagnosis had been confirmed on subsequent visits The straight leg raising test had been positive on each occasion and the strength of the extensors to the big toe had been reduced In addition to these symptoms palpation of the knee joint disclosed a mass in such a position—in the posterior region on a level with the lateral joint line—that it could conceivably exert pressure on the peroneal nerve and hence be the cause of the patient's symptoms This seemed still more likely after myelography had shown no sign of a prolapsed disk Operation revealed a ganglion cyst of the lateral meniscus and a protruding posterior part of it was seen to stretch the peroneal nerve at full extension in the knee joint (Figure 5) while at flexion the tension was reduced the nerve appeared macroscopically intact The lateral meniscus had ruptured (Figure 6) and was removed together with the ganglion The leg raising test was negative the first post operative day and the extension of the big toe was then almost as strong as in the other foot The improvement has remained for one year and three months

COMMENT

It is probably unusual for a ganglion cyst of the lateral meniscus to exert pressure on the peroneal nerve At all events this cause of symptoms from the peroneal nerve is not mentioned in current textbooks and manuals of orthopaedic surgery *Hertz* (19..) reports that a patient with a ganglion cyst of the lateral meniscus displayed a slight hypersensitivity in the peroneal region which disappeared immediately after the operation and concluded that the ganglion had probably caused these paraesthesias by compressing the nerve However the exposure used for removal of the ganglion did not permit the demonstration of any such compression Recently *Coker & Kent* (1967) described two cases in which symptoms from the peroneal nerve were ascribed to a ganglion cyst of the lateral meniscus In one of these the

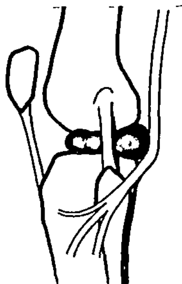


Figure 5 Case 4 Ganglion cyst of the lateral meniscus protruding in a dorsal direction and exerting pressure on the peroneal nerve



Figure 6 Case 4 The removed lateral meniscus showing a transverse rupture together with ganglion cyst Arrow points to the dorsal part of the ganglion that exerted pressure on the peroneal nerve (cf Figure 5)

ganglion protruded posteriorly and although involvement of the nerve was not observed directly (the nerve was not exposed) an area of hyperaesthesia in the first web space dorsally on the foot present before the operation disappeared after In the other case the patient had a sensory disturbance in the innervation field of the peroneal nerve before the operation at which a ganglion cyst of the lateral meniscus was found "adjacent to the nerve The sensory disturbance gradually disappeared after the operation It is noteworthy that the cyst could not be palpated at the clinical examination in either of these two cases

Coker & Kent were unable to determine whether it was pressure from the cyst or some other mechanism that resulted in irritation of the nerve During the operation in the present case the nerve was seen to be stretched over the ganglion at full extension in the knee joint while at flexion the tension was reduced The positive leg raising test before the operation was no doubt a result of this test being made with the

knee joint extended Since the big toe extensors practically regained their normal strength the day after the operation their pronounced weakness before must have had a functional cause (inhibition elicited by pain?)

Case 5

A 61 year old man with pain periodically for two years in the left leg had during the last two months noticed a swelling on the outside of the left knee joint. Examination showed a mass located over the postero lateral aspect of the upper portion of the fibula and there was marked peroneal paresis with foot drop and impaired sensibility on the outside of the leg and foot. The clinical diagnosis was a Schwannoma Operation however disclosed a ganglion largely located within the peroneal nerve whose fibre bundles were split and flattened (Figure 7) The intra neural part of the ganglion had a thin connection with an extraneural part located anterior to the proximal tibio fibular joint The ganglion was removed leaving part of its wall which contained bundles of nerve fibres Its content was clear and gelatinous the histological picture was that of a ganglion No signs of recurrence were found at an examination one year after the operation A considerable improvement was observed in the motor function of the peroneal nerve (active dorsal extension 10) and its skin area was sensitive to touch though this elicited paraesthesias in the foot and the distal third of the leg

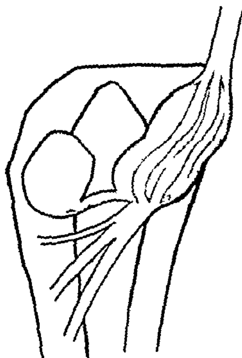


Figure 7 Case 5 Intraneural ganglion in the left peroneal nerve Part of the ganglion is located near the proximal tibio fibular joint

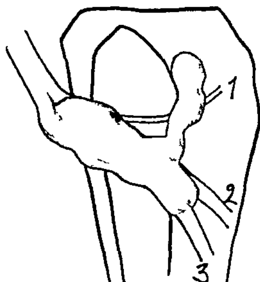


Figure 8 Case 6 Intraneural ganglion in the right peroneal nerve The ganglion has a pedicle extending to the proximal tibio fibular joint 1) Nerve branch to the tibialis anterior muscle 2) The deep peroneal nerve 3) The superficial peroneal nerve



Figure 9 Case 6 The extirpated ganglion

Case 6

A 46 year old man had had pain on the outside of the right leg for five months During the last few weeks he had also felt weakness in the foot and numbness in the big and second toes Examination revealed marked paresis of the big toe extensors and impaired sensibility on the outside of the leg and down the anterior surface of the ankle to the big toe and the medial side of the second toe Furthermore a firm tender mass was palpated at the place where the peroneal nerve passes round the neck of the fibula. At operation the mass was found to be a ganglion located in the peroneal nerve (Figure 8) The deep portion of the nerve was flattened between the ganglion and the neck of the fibula, whereas the superficial portion was embedded in the postero lateral wall of the ganglion A thin extension of the ganglion reached the anterior side of the proximal tibio fibular joint being crossed at a deeper level by a fairly small nerve branch to the tibialis anterior muscle The entire ganglion could be removed (Figure 9) without severing any nerve fibres Histological examination confirmed the diagnosis and showed that the ganglion was multilocular No signs of recurrence were detected at an examination four months after the operation The strength of the extensors of the big toe had been recovered but the sensibility was still impaired The pain had not returned since the operation

COMMENT

An intraneural ganglion in the peroneal nerve is unusual. Cases have been reported by *Wadstein* (1932), *Ellis* (1936), *Ferguson* (1937), *Warren* (1946), *Brooks* (1952), *Tupman* (1957), *Clark* (1961), *Parkes* (1961), *Barrett & Cramer* (1963) and *Stack, Bianco & MacCarty* (1965). Cases similar to the two in this paper with the ganglion having an extraneural part in close relation to the proximal tibio-fibular joint have been described by *Warren* (1 case), *Brooks* (1 case), *Parkes* (1 cases), *Barrett & Cramer* (1 case) and *Stack et al.* (2 cases). According to *Parkes* the ganglion arises from the proximal tibio-fibular joint and then by tracking along the sheath of the small recurrent articular branch which is given off from the peroneal nerve to this joint it comes to lie within the sheath of the main nerve where it is free to enlarge and extend. Working on this assumption he argues that the essential step at operation is to find and extirpate the pedicle, while it is enough just to evacuate the intraneural part of the ganglion. *Barrett & Cramer* however suggest that the ganglion originates in the main nerve and that an extension into the articular branch of the proximal tibio-fibular joint may give the false impression that the ganglion has arisen from this joint. Their view is supported by the fact that completely intraneural ganglia without any connection to joint or bursa do occur (*Friedlander* 1967).

SUMMARY

Six cases of unusual ganglion cysts in the neighbourhood of the knee joint are described.

In two cases the main part of the ganglion was located within muscle suggesting a primary muscle tumour.

In one case a large ganglion cyst of the lateral meniscus protruded between the patellar tendon and the ilio-tibial tract, giving rise to a subcutaneous lump in front of the knee.

In one case a ganglion cyst of the lateral meniscus protruded in a posterior direction to such an extent that it exerted pressure on the peroneal nerve with neurological symptoms as a result.

In two cases the main part of the ganglion was located within the peroneal nerve, a smaller part being found outside the nerve near the proximal tibio-fibular joint. Twelve cases of peroneal intraneural ganglion with a pedicle to the proximal tibio-fibular joint have been found in the literature. The origin of such a ganglion is discussed.

REFERENCES

Barrett, R. & Cramer F (1963) Tumors of the Peripheral Nerves and so-called Ganglia" of the Peroneal Nerve *Clin Orthop* 27 135–146

Brooks D M (1952) Nerve Compression by Simple Ganglia. *J Bone Jt Surg* 34 B 391–400

Clark, K. (1961) Ganglion of the lateral Popliteal Nerve *J Bone Jt Surg* 43 B 778–783

Coker T P & Kent M (1967) Peroneal Nerve Irritation Associated with Cystic Lateral Meniscus of the Knee *J Bone Jt Surg* 49 A 262–264

Ellis V H (1936) Two cases of Ganglia in the Sheath of the Peroneal Nerve *Brit J Surg* 24 141–142

Ferguson L. K. (1937) Ganglion of the Peroneal Nerve *Ann Surg* 106 313–316

Friedlander H. L. (1967) Intraneural Ganglion of the Tibial Nerve *J Bone Jt Surg* 49 A 519–522

Hertz J (1955) Cysts of the Semilunar Cartilage of the Knee-Joint. *J International College Surg* 24 257–264

Parkes A (1961) Intraneural Ganglion of the lateral Popliteal Nerve *J Bone Jt Surg* 43 B 784–790

Smillie I S (1962) Injuries of the Knee Joint. E. & S Livingstone Ltd Edinburgh and London

Stack, R. E. Bianco A J & MacCarty C. S (1965) Compression of Common Peroneal Nerve by Ganglion Cysts *J Bone Jt Surg* 47 A 773–778

Tupman G S (1957) Axonotmesis of Anterior Tibial Branch of Lateral Popliteal Nerve Due to Ganglion of the Nerve Sheath *Brit J Surg* 45 23–24

Wadstein T (1932) Two Cases of Ganglia in the Sheath of the Peroneal Nerve. *Acta orthop scand* 2 221–231

Warren R. (1946) Ganglion of the Common Peroneal Nerve *Ann Surg* 124, 152–155

Acta orthop. Scandinav. 40, 402–408, 1969

Department of Orthopaedic Surgery, Sorø, Denmark.
Head: Erik Madsen, M.D.

THE TREATMENT OF HALLUX VALGUS BY DISTAL OSTEOTOMY OF THE 1st METATARSAL

HUGH DOVEY[1]

Received 4.x.67

The number of operations used in the treatment of a deformity is usually in inverse proportion to the success of the treatment; there are about seventy different operations which have been used in the treatment of hallux valgus (1), and the results after operations are correspondingly uncertain. Although one is reluctant to add another variant to the list, the procedure described first by *Mygind* 1953 (2) and modified by Erik Madsen gives consistently good results in suitable cases, and the technique, although exact, is essentially simple.

OPERATION

The procedure consists of a wedge osteotomy of the 1st metatarsal performed as distally as possible without opening the metatarsophalangeal joint (Plate I). The head of the metatarsal is displaced laterally and plantar, thereby correcting all elements of the foot deformity, restoring the normal axis of the big toe, narrowing the foot, relieving pressure on the 2nd and 3rd metatarsal heads and the symptoms of metatarsalgia, and relaxing tension in the soft tissues on the lateral side of the metatarsophalangeal joint, particularly the adductor hallucis, so that tenotomy is unnecessary. The osteotomy is done through the cancellous bone of the metatarsal head, so that bony union presents no problem.

---

[1] Now Assistant Director, Surgical Department M, Bispebjerg Hospital, Copenhagen.

Acknowledgements are made to Senior Surgeon *Erik Madsen* for his help and encouragement in writing this paper.

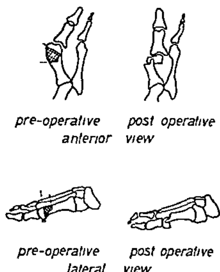


Figure 1 Wedge osteotomy of head and neck of 1st metatarsal

The operation is performed under a dry field through a dorso medial incision and the osteotomy is made with the narrow blade of the oscillating saw the distal cut is oblique through the cancellous bone of the metatarsal head the proximal cut transverse with a small peg located laterally and plantar on the metatarsal shaft care is needed in forming the peg as the cortical bone is liable to splinter A small hole is fashioned in the cancellous bone of the distal fragment to accomodate this proximal bone peg this hole should be dorsal and medial in the cancellous bone so that maximal displacement plantar and laterally is achieved After displacement of the osteotomy and impaction of the bony peg the position is maintained by a stainless steel suture passed through bore holes in the dorsal cortex Cancellous chips from the wedge of bone removed at osteotomy are packed around the osteotomy site particularly laterally The tourniquet is released after wound closure

The position of the osteotomy should be stable without external fixation but a plaster sole is applied to forefoot and heel well moulded around the big toe—although not a circular plaster—to prevent redis placement Sutures are removed after fourteen days and the plaster is changed to a walking sole which is worn for 4 weeks weight bearing is begun after removal of the sutures After removal of the plaster 6 weeks post operatively a canvas forefoot sling is fitted to prevent

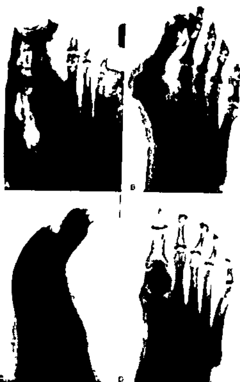


Figure 2 X rays pre-operatively (top left) immediately post operatively (top right) and the same foot 9 years later (bottom left and right)

spreadfoot and flattening of the transverse arch and this should be worn for at least a year after operation Plate II shows a typical X ray before and after operation and Plates III and IV clinical photographs before operation and two years later



Figure 3 Bilateral hallux valgus deformity before operation
Figure 4 The same case 2 years after operation

CLINICAL MATERIAL

The series consists of eighty four operations in fifty six patients performed between 1953 and 1963 in the Department of Orthopaedic Surgery Sorø Denmark. Age of the patients varied from sixteen to seventy four with an average of forty five the operation should not be performed until the foot is fully developed but there is no upper age limit to the procedure provided there is good mobility of the meta tarso phalangeal joint Sex distribution was fifty women to six men a ratio of 8 3 1 and there was a family history of deformity in thirty one patients (55 per cent) Clinical symptoms had varied from one to twenty five years and had been present on the average for five years almost all patients complained of a painful exostosis and almost half the number of metatarsalgia (Table 1) associated foot deformities *e g* clawing of the toes and flattening of the transverse arch were noted in fifty two patients (93 per cent)

Table 1 Pre operative symptoms

	Patients	*Per cent*
Painful exostosis	54	97
Metatarsalgia	26	47
Pain and stiffness of the 1st metatarso phalangeal joint	8	14

RESULTS

Proper assessment of the results of foot surgery is difficult as most adults have painful feet from time to time The results were therefore classified as good moderate and poor those with good results were entirely satisfied with the operation had no clinical deformity and were pain free at work and after normal use of their feet those with moderate results included patients who were satisfied with the result and had no regrets that they had undergone operation but had occa sional pain after normal exercise or recurrence of slight deformity poor results comprised unsatisfied patients with pain or recurrent deformity or both The results are shown in Table 2

Table 2 Operative results

Good	61 feet	73 per cent
Moderate	21 feet	25 per cent
Poor	2 feet	2 per cent

More detailed examination of the moderate and poor results is shown in Table 3

In the moderate series most patients complained of metatarsalgia stiffness of the 1st metatarso-phalangeal joint was an occasional com

plant and it was necessary to remove the stainless steel suture in four cases on account of discomfort under the scar. This was performed without difficulty under local anaesthetic.

The poor results comprised one patient with severe metatarsalgia and one with painful hallux rigidus; in both cases these had been major symptoms before operation and this procedure should not have been used.

Table 3. Analysis of moderate and poor results

Moderate		
1	Metatarsalgia	15 feet
2	Painful scar (requiring removal of stainless steel suture)	4 feet
3	Recurrence of deformity	2 feet
4	Pain and stiffness of 1st metatarso-phalangeal joint	6 feet
5	Numbness of medial border of hallux	1 foot
Poor		
1	Severe metatarsalgia	1 foot
2	Severe hallux rigidus	1 foot

X-RAYS

All patients were X-rayed for the purpose of this follow-up examination; one case of non-union was found but since the patient was symptom-free no treatment was undertaken. The X-rays of the operated series were compared with a control series of sixty patients with normal feet, with special reference to the length of the 1st metatarsals before operation, the angle between 1st and 2nd metatarsals and the angle between 1st and 5th metatarsals, the angle of spreadfoot (Table 4).

Table 4. Comparison of X-rays with control series

1	Length of 1st metatarsal	
	Author's series	Average 5·9 cm
	Control series	Average 5·7 cm
2	Angle between 1st and 2nd metatarsal	
	Author's series	Average 12
	Control series	Average 5
3	Angle between 1st and 5th metatarsals (spreadfoot)	
	Author's series	Average 30
	Control series	Average 18

It can be seen from Table 4 that while there is no great difference in the length of the 1st metatarsals in the two series, both the angle between 1st and 2nd metatarsals and also the angle of spreadfoot are significantly increased in patients with hallux valgus, and this confirms the impression that the deformity is part of a generalised foot

syndrome in which flattening of the transverse arch and spreadfoot are among the most important features

SUMMARY AND CONCLUSIONS

1 Hallux valgus is part of a generalised foot deformity in which an important factor is spreadfoot

2 Treatment by a distal wedge osteotomy of the 1st metatarsal with displacement of the distal fragment laterally and plantar corrects all elements of the deformity and the procedure can be used in all age groups once the foot is fully developed in this series of eighty four operations the operation gave satisfactory results in eighty two cases (97 per cent)

There were no cases of infection

3 The operation is not advised in cases of hallux rigidus or severe metatarsalgia but it can be expected to relieve the symptoms in most cases of moderate metatarsalgia

RESUME

1 Hallux valgus est la partie d une deformite generalisée du pied dont un important facteur est l affaissement du pied

2 Le traitement par osteotomie distale en coin du premier métatarsien avec déplacement du fragment distal lateralement et plantairement corrige tous les élements de la déformite Cette maniere de proceder peut etre utilisée dans tous les groupes d âge une fois que le pied est entièrement développe dans cette série de 84 opérations l intervention a donné des résultats satisfaisants dans 82 cas (97 pour cent) Il n y a pas eu un seul cas d infection

3 L opération n est pas recommandee dans les cas de Hallux rigidus ou de grave métatarsalgie mais elle peut apporter un soulagement dans la plupart des cas de métatarsalgie modérée

ZUSAMMENFASSUNG

1 Hallux valgus ist Teil einer allgemeinen Fussverbildung deren wichtiger Faktor der Spreizfus ist

2 Behandlung mittels distaler Keilosteotomie des ersten Mittelfuss knochens mit Verschiebung des distalen Fragmentes lateral und plantar korrigiert alle Bestandteile der Deformitet und das Vorgehen kann in allen Altersgruppen verwendet werden sobald der Fuss voll ent

wickelt ist In dieser Reihenfolge von vierundachzig Operationen ergab die Operation in zweiundachzig Fällen ein zufriedenstellendes Resultat (97 Prozent) Kein Fall von Infektion entstand

3 Die Operation wird in Fällen von Hallux rigidus oder schweren Metatarsalgien nicht empfohlen, kann aber erwartungsgemäss die Symptome in den meisten Fällen von moderaten Metatarsalgien zum Verschwinden bringen

REFERENCES

1 Mitchell C Leslie (1956) Exhibit on the treatment of hallux valgus *J Bone Jt Surg* 38 A 540

2 Mygind H B (1953) Operative treatment of hallux valgus *Ugeskr Læg* 12 237

Acta orthop Scandinav 40 409–410 1969



Sten Friberg

When Sten Friberg retires from the chair of orthopaedic surgery at the Karolinska Institute Stockholm a chair which he has held for more than 25 years he can look back on a tremendous development of orthopaedics in Sweden At the time of his appointment as professor there was only one university service in orthopaedic surgery in Sweden Now there are eight The evolution of orthopaedics within the general hospitals has paralleled this and orthopaedic surgery is now repre sented as a subject of its own in all central county hospitals Sten Friberg has been a leading force in this development Above all he

has constantly pursued the concept of orthopaedic surgery as an organ specialty, i.e. a specialty for the care of disease *and trauma* in the locomotor system. These ideas are now generally accepted and development is going on along those lines in good harmony with the general surgeons.

Sten Friberg's personal scientific interests have been devoted very much to studies of the lumbar spine. A really original source of knowledge of spondylolisthesis was presented in his thesis in 1939, always cited in new papers on the subject. Through the years 1940-1950 Sten Friberg and his collaborators particularly studied the problems of low back pain and sciatica and its relation to disc herniation. In numerous papers different clinical and pathoanatomical aspects were analysed and the understanding of low back pain was much broadened.

In the year 1951 Sten Friberg was appointed Rector of the Karolinska Institute in a period of very rapid development on the Swedish university scene. The achievements of Sten Friberg as a university man have been highly esteemed and officially rewarded by the Swedish government. His interest in scientific and clinical organization and his socio-medical responsibility, for instance in insurance medicine, where Sten Friberg's humane judgements often have played a conclusive part in difficult cases, are well appreciated. In the Scandinavian orthopaedic field Sten Friberg has been a successful editor of *Acta Orthopaedica Scandinavica*. Internationally one of his great contributions lies in being the current president of SICOT.



Gunnar Wiberg

At the end of June 1969 Gunnar Wiberg retires as head of the Orthopaedic Clinic in Lund a post he has held since 1945 and which became a professorial chair in orthopaedics in 1947

During this period he has had as clinical head an ever increasing amount of administrative and teaching responsibilities and added to this have been his scientific contributions which have covered many fields and in which he has distinguished himself He has simultaneously been actively involved in the functioning of a large clinic and the care of patients whom he has always considered to be of prime importance

His contributions towards orthopaedics have among other things ranged from hip surgery and the definition of the CL angle to investigations into the mechanism of pain in disc protrusion the patello-femoral joint with special regard to chondromalacia

His administrative and professional capacities have been made full use of as president of the Swedish Orthopaedic Association as a member of the Board of the Scandinavian Orthopaedic Association as director of the Southern Swedish School of Physiotherapy as medical superintendent and is a member of the Hospital Administration as president of the Swedish Medical Disciplinary Committee and on the editorial staff of *Acta Orthopaedica Scandinavica*

Great is the number of orthopaedic surgeons who have trained under his stimulating guidance gaining in knowledge both theoretical and practical and all proud to have been associated with him The tone between different categories has always been free and open Gunnar Wiberg always seems happiest during a heated discussion especially when students have participated in a spirit of free discussion and criticism

Two factors have helped Gunnar Wiberg to manage the large volume of work and these are his excellent physical condition and his lively sense of humour

The vitality he possesses and the atmosphere of team work together with the will to accept new ideas have involved him in the wearisome details connected with the shifting of the orthopaedic clinic to the new central block of the hospital in Lund

Gunnar Wiberg has been one of the foremost internationally known Swedish orthopaedic surgeons a great traveller and honoured guest His many friends around the world will certainly expect to see even more of him in years to come

Acta orthop Scandinav 40 413–428 1969

From the Department of Clinical Chemistry Danderyd (Head G Widstrom)
the 4th Department of Medicine Sodersjukhuset (Head L Engstedt) and the
Orthopaedic Clinic Karolinska Institutet (Head S Friberg)

ELEVATION OF ORNITHINE CARBAMOYL TRANSFERASE IN SERUM (S OCT) NITROGEN LOSS AND POTASSIUM LOSS AS METABOLIC RESPONSE TO SKELETAL AND ABDOMINAL OPERATIONS

JOHAN BROHULT ULF NILSONNE & KARL ERIK OLSSON

Received 24 iii 68

The increase in the urinary excretion of nitrogen that occurs after surgical trauma (*Cuthbertson* 1945 *Howard* 1945 *Moore & Ball* 1952) has been interpreted as an effect of tissue trauma leading to increased tissue catabolism (*Krieger et al* 1954) The breakdown of tissues after an operation is a general phenomenon however and not just confined to the operation field (*Krieger et al*) Protein anabolism takes place even during the earliest phase after the trauma though on a smaller scale than the catabolism (*Blocker et al* 1955) Many causes of the postoperative catabolism have been reported e g the increased production of adrenal corticosteroids impaired resorption as a result of intestinal dysfunction inadequate supply of calories and muscular atrophy as a result of postoperative immobilization (*Roberts* 1953 *Holden et al* 1957 *Jungner & Jungner* 1960 *Wetterfors* 1965)

The postoperative protein catabolism that is reflected in the increased urinary excretion of nitrogen has been regarded as a measure of the size of the surgical trauma (*Moore* 1959) as has the increased excretion of potassium (*Moore Steenburg et al* 1955) The majority of metabolic studies have been conducted on cases of abdominal surgery Since there is reason to suppose that the metabolic picture is different after skeletal operations we decided to study this question by comparing two groups of cases of skeletal and abdominal operations respectively

METHODS

Anesthesia

General anesthesia with halothane and tracheal intubation was given according to the technique described elsewhere (*Brohult 1967*) Exceptions were case 13 with spontaneous respiration and case 6 in which the operation was performed under spinal anesthesia with Tetracaine grave® The anesthesia was free from complications in every case No systolic blod pressure below 95 mm Hg was recorded nor did this pressure ever drop by more than 35 mm Hg

Sampling

Urine was collected in 24 hour samples which were measured daily from the first preoperative to the 14th postoperative day and analyzed for total nitrogen potassium 17 hydroxycorticosteroids and creatinine As the urine samples could not always be collected consistently however analyses were not performed on all of them (cf Tables 3 5) Moreover analyses of the 17 hydroxycorticosteroids in urine were only performed in cases 1–4 and 8 13

Samples of venous blood were taken the day before the operation the day of the operation and days 1 4 7 8 and 11 after the operation In some cases samples were also taken on days 2 and 14 The samples were taken in the morning with the patient fasting and were analyzed for S OCT

Analyses

By reproducibility (coefficient of variation) is meant the error of the method calculated from duplicate determinations and expressed as a percentage of the mean of the duplicate determinations Generally accepted methods were used for the statistical analyses (*Dickson & Massey 1957*)

The OCT activity was determined by incubating serum with citrulline carbamoyl ^{14}C in arsenate buffer (*Reichard 1964*) The results are expressed in nanomoles (nm) ^{14}CO liberated by 0.5 ml serum in two hours incubation under standard conditions. Normal value <4.0 nm (*Beckman et al 1966*) Reproducibility 8 per cent

Total nitrogen in urine was determined according to Kjeldahl on the principles of *Hiller et al* (1948) Reproducibility 4 per cent Urinary 17 hydroxycorticosteroids were analyzed according to a method for estimating all corticosteroids possessing a 17 hydroxyl group (*Birke et al* 1958) Reproducibility 6 per cent. Potassium was analyzed with a flame photometer (Instrumentation Laboratory Inc Boston) according to the principles of *Barnes et al* (1945) Reproducibility 4 per cent

RESULTS

Orthopaedic Operations

The S OCT activity averaged 1 8 nm before and 1 9 nm immediately after the operation On day 1 it averaged 2 1 nm and on day 4 7 0 nm The mean for day 4 is significantly different from the mean initial value ($p < 0.05$) On day 7 the S OCT activity averaged 6 2 nm on day 8 5 0 nm and on day 11 3 8 nm (see Figure 1 and Table 2)

Table [illegible] S OCT activity before and after orthopedic operations (Cases 1–7) and abdominal operations (Cases 8 14)

Case No	Before op	After op	Day after operation 1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	1 3	1 4	1 1			4 0			2 6	1 7			1 6			
2	2 0	1 6	2 6	2 9		5 6			3 3	1 9			0 7			1 3
3	2 8	4 5	5 0			8 5			6 9	3 8			3 1			1 8
4	3 6	2 7	4 0			18 4			20 3	17 5			14 1			5 6
5	1 4	1 6	1 1			8 3			6 2	3 4			2 0			0 6
6	0 9	0 4	0 5			2 5			1 5	1 0			0 7			
7	0 9	1 2	0 6	0 3		1 7			2 4	5 8			4 1			3 2
Mean	1 8	1 9	2 1	1 6		7 0			6 2	5 0			3 8			2 5
S D	1 0	1 3	1 8			6 7			6 5	5 7			4 7			2 0
8	3 1	2 3	5 4			28 9			22 8	20 8			6 9			5 2
9	1 9	1 7	2 6	4 0		21 1			14 2	9 0			3 5			1 4
10	0 9	1 6	1 3			12 5			17 0	18 4			7 7			
11	2 5	2 9	2 7	7 0		32 3			35 6	26 0			15 1			6 1
12	2 2	4 2	2 1			24 8			27 2	25 8			6 5			1 8
13	0 9	0 7	0 2			1 8			1 7							
14	1 5	1 2	0 8	1 1		3 7			4 6	3 6			0 6			
Mean	1 9	2 1	2 2	2 7		17 9			17 6	17 3			6 7			3 6
S D	0 8	1 2	1 7			12 1			12 1	9 1			4 9			

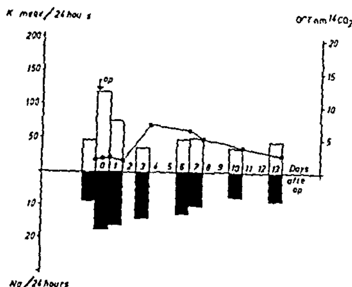


Figure 1 Mean S OCT activity (●——●) nitrogen (filled bars) and potassium (empty bars) in seven orthopedic operations

The excretion of nitrogen averaged 8.8 g per 24 hours before the operation and 17.6 g during the first 24 hours after the operation. The difference is statistically significant ($p < 0.02$). The average excretion of nitrogen declined continuously from the 2nd postoperative day onwards (see Figure 1 and Table 3).

The average excretion of potassium was 48 mEq per 24 hours before the operation and 119 mEq during the first 24 hours after the operation. The difference is statistically significant ($p < 0.05$). The mean level decreased from the second postoperative day (see Figure 1 and Table 4).

The excretion of 17 hydroxycorticosteroids in the four cases studied averaged 8.5 mg per 24 hours before the operation and 31.5 mg on the first postoperative day. The average level showed a continuous decline from the second postoperative day (see Table 5).

Abdominal Operations

The S OCT activity averaged 1.9 nm before and 2.1 nm immediately after the operation. On day 1 it averaged 2.2 nm, on day 4 17.9 nm and on day 7 17.6 nm. The means for days 4 and 7 both differ significantly from the mean initial value ($p < 0.01$ and < 0.02 respectively). The

Table 3 Excretion of nitrogen in urine before and after orthopedic operations (Cases 1-7) and abdominal operations (Cases 8-14)

Case No.	Preop day	Day after operation														
		0 1	1-2	2-3	3 4	4-5	5 6	6-7	7 8	8-9	9-10	10-11	11-12	12-13	13-14	14-15
1	6 3	7 5	13 9	6 5	10 3	9 5	9 5	7 4	7 4	9 2	9 7	4 8	9 9	11 8	8 7	6 3
	7 3	19 8	9 5	9 4	9 5	8 6	6 9	7 4	8 0	8 4	7 7	9 0	8 5	8 1	8 8	
3	3 7	5 9	3 3	3 2	8 6	4 9	5 4	4 2	2 1	3 7	3 8	2 4	2 8	3 4	4 7	2 4
4	11 7	20 9	20 8	17 0	13 6	13 6		13 1	9 2	13 4	14 2				11 7	
5	5 5	23 6	28 0		21 3	13 8	17 5	14 2	18 2	9 5	13 0					
6	15 0	18 9	9 2	9 2	9 2	8 0		8 8	8 8	12 0						
7	12 3	27 0	28 8	22 2	25 2	31 2	31 2	33 8	17 4	14 5	12 0	13 3	16 2	12 3		
Mean	8 9	17 6	16 2	11 3	14 0	12 8	14 1	12 7	10 2	10 1	10 1	7 4	9 4	8 9	8 5	
SD	4 2	8 0	9 9	7 0	6 6	8 7	10 6	9 9	5 7	3 6	3 9					
8	11 7	34 0	28 4		19 0			13 1	14 5			8 4			9 8	
9	6 6	27 3	29 2		21 6			16 5				12 3			8 9	
10	10 8	5 0	23 7		14 9			1 6				11 2				
11	10 0	43 4	37 5		32 8			24 1	18 1			20 3			13 2	
1	11 2	59 6	40 6		29 4			14 7	16 3			8 9			11 2	
13	6 8	7 7	5 3		10 5			6 8								
14	4 1	22 2	12 5		9 0			5 0	5 8							
Mean	8 7	31 3	5 3		19 6			13 7	13 7			12 2			10 8	
SD	2 9	16 3	12 7		9 1			6 4				4 8				

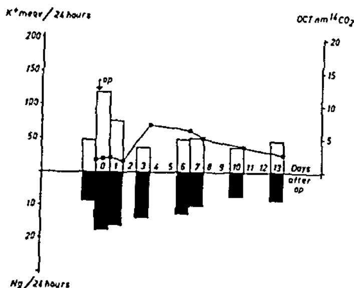


Figure 1 Mean S OCT activity (●——●) nitrogen (filled bars) and potassium (empty bars) in seven orthopedic operations

The excretion of nitrogen averaged 8.8 g per 24 hours before the operation and 17.6 g during the first 24 hours after the operation. The difference is statistically significant ($p < 0.02$). The average excretion of nitrogen declined continuously from the 2nd postoperative day onwards (see Figure 1 and Table 3).

The average excretion of potassium was 48 mEq per 24 hours before the operation and 119 mEq during the first 24 hours after the operation. The difference is statistically significant ($p < 0.05$). The mean level decreased from the second postoperative day (see Figure 1 and Table 4).

The excretion of 17 hydroxycorticosteroids in the four cases studied averaged 8.5 mg per 24 hours before the operation and 31.5 mg on the first postoperative day. The average level showed a continuous decline from the second postoperative day (see Table 5).

Abdominal Operations

The S OCT activity averaged 1.9 nm before and 2.1 nm immediately after the operation. On day 1 it averaged 2.2 nm, on day 4 17.9 nm and on day 7 17.6 nm. The means for days 4 and 7 both differ significantly from the mean initial value ($p < 0.01$ and < 0.02 respectively). The

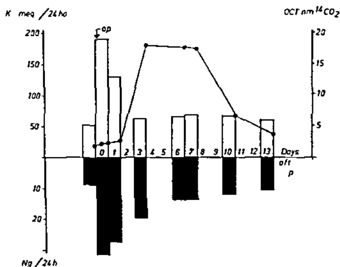


Figure 2 Mean S OCT activity (●——●) nitrogen (filled bars) and potassium (empty bars) in seven abdominal operations

S OCT activity averaged 17 3 nm on day 8 and 6 7 nm on day 11 (se Figure 2 and Table 2)

The excretion of nitrogen averaged 8 7 g per 24 hours before the operation and 31 3 g during the first 24 hours after the operation The difference is statistically significant ($p < 0\ 01$) The average excretion decreased continuously from the second postoperative day but on day 7 it was still significantly higher than the initial preoperative value ($p < 0\ 05$) (see Figure 2 and Table 3)

The excretion of potassium averaged 53 mEq per 24 hours before the operation and 190 mEq during the first 24 hours afterwards The difference is statistically significant ($p < 0\ 01$) The mean level de creased from the second postoperative day (see Figure 2 and Table 4)

The excretion of 17 hydroxycorticosteroids in the six cases studied averaged 9 9 mg per 24 hours before the operation and 50 0 mg on the first postoperative day The difference is statistically significant ($p < 0\ 05$) The mean level decreased continuously from the second post operative day (see Table 5)

Comparison between the Two Groups

The postoperative excretion of nitrogen was greater after the ab dominal operations than after the skeletal operations ($p < 0\ 05$) As

Table 5 Excretion of 17 hydroxycorticosteroids in urine before and after orthopedic operations (Cases 1–7) and abdominal operations (Cases 8–14)

Case No	Praeop day	Day after operation 0–1	1–2	2–3	3–4	4–5	5–6	6–7	7–8	8–9	9–10	10–11	11–12	12–13	13–14	14–15
1	3 8	15 0	29 2	21 8	17 0	9 8	9 8	8 8	7 9	9 8	10 7	5 4	8 7	5 9	4 3	3 8
2	8 7	25 5	11 3	11 1	6 2	7 3	8 4	8 5	10 3	7.3		10 4	8 0	6 7	9 9	
3	5 9	13 5			8 6		5 4	6 7	6 3	9 1	4 6		6 0	7 7		
4	15 6	72 0		35 7	20 5	20 5		18 0	8 3	10 6	12 5				15 6	
5																
6																
7																
Mean	8 5	31 5	20 3	22 9	13 1	12 5	7 9	10 0	8 2	9 2	9 3	7 9	7 6	6 8	9 9	
S D	5 1	27 5			6 8			5 4	1 6	1 4						
8	10 2	48 6			24 4			11 3	12 7			8 8			9 0	
9	11 0	45 4	30 0					9 4							7 5	
10	7 5	38 7	24 5		19 6			8 9				5 5				
11	14 8	68 1	43 2					20 5	14 9			16 7			15 2	
12	9 3	87 3						23 6				10 9			9 3	
13	6 9	12 0	11 3		7 1			6 9								
14																
Mean	9 9	50 0	27.3		17 0			13 4	13 8			10 5			10 3	
S D	2 8	25 7	13 2					8 9				4 7			3 4	

Table 6 The relationship between the S OCT increase on day 4 and on day 7 (y) and the postoperative increase (per m² body surface) in the excretion of nitrogen (g/24 hours) potassium (m Eq/24 hours) and 17 hydroxycorticosteroids (mg/24 hours) (x) as well as the relationship between these different excretion variables

y	x	n	r	P	Equation of regression line	SD reg line
S OCT_{4-0}	Nitrogen	14	0.74	<0.01	y = 0.98[illegible]x + 2.0[illegible]	7.1
S OCT_{4-0}	Potassium	14	0.80	<0.001	y = 0.183x + 0.05	6.4
S OCT_{4-0}	17-OHCS	10	0.76	<0.0[illegible]	y = 0.578x + 2.62	7.1
S OCT_{7-0}	Nitrogen	14	0.77	<0.01	y = 1.066x + 0.74	7.0
S OCT_{7-0}	Potassium	14	0.78	<0.01	y = 0.187x — 0.71	6.9
S OCT_{7-0}	17 OHCS	10	0.84	<0.01	y = 0.68[illegible]x + 0.01	6.5
Nitrogen	Potassium	14	0.86	<0.001	y = 0.149x + 0.12	4.0
Nitrogen	17 OHCS	10	0.88	<0.001	y = 0.564x — 1.31	4.5
17 OHCS	Potassium	10	0.83	<0.01	y = 0.247x + 3.81	8.1

will be seen from Tables 2–5 it took longer time for most of the abdominal cases to return to the initial levels for S OCT and the urinary excretion of nitrogen potassium and 17 hydroxycorticosteroids

Correlation Analysis

The increases in S OCT on days 4 and 7 are significantly correlated to the postoperatively increased excretions (per m² body surface) of nitrogen potassium and 17 hydroxycorticosteroids (17 OHCS) More over the increase in any one of these latter three variables is significantly correlated to the increase in each of the other two (see Table 6)

DISCUSSION

The clinical assessment of the size of a surgical trauma—based on variables such as blood loss duration of the operation and anatomical exploration—may differ considerably from the result of concomitant metabolic studies With modern anesthetic techniques optimal postoperative administration of fluids and calories an early switch to peroral nutrition and early postoperative mobilization it seems likely that the metabolic reaction to surgical trauma is less than it used to be (*Moore & Ball*)

Major orthopedic operations often involve considerable destruction of tissue Amputations such as hemipelvectomy and arthrodeses of large

joints cannot usually be *performed without extensive* anatomical exploration of the operation field Moreover orthopedic cases often have to be immobilized to varying degrees after the operation Plaster bandages or some other form of immobilization inevitably cause a reduction of physical activity Efforts are naturally made to limit these measures, *since the immobilization gives rise to a considerable* catabolism of the body tissues (*Jungner & Jungner*) Attempts have likewise been made to reduce the postoperative catabolism after abdominal operations *i e* by early mobilization and an early switch to peroral nutrition in order to get the digestive apparatus functioning normally as *soon as possible Earlier studies* have demonstrated a negative nitrogen balance in operated cases for several weeks after the operation (Howard) but many of the present cases returned to the preoperative level after only one week It seems very probable that this was due to a consistent application of the principles of active treatment above

The present results indicate that the tissue catabolism was less pronounced in the orthopedic than the abdominal cases This is evident from the higher urinary excretion of nitrogen in the abdominal cases The disparate reactions demonstrated for these two groups suggest that the metabolic effect of surgical trauma can be assessed more specifically *than has been reported by* Moore and *Ball*

As far as the orthopedic cases are concerned one of the reasons for this study was the frequently observed, marked clinical difference in the postoperative course between *e g* a hip arthrodesis and a hemipelvectomy The former generally affects the patient s general status with muscular asthenia *during the first 24 hours A hemipelvectomy* on the other hand has remarkably little influence on the physical condition (*Nilsonne et al* 1968) Although the surgical extent and duration of these operations are relatively similar the metabolic reactions are very different Hip arthrodesis elicits a much greater tissue *catabolism partly because of the surgical destruction* of muscle and partly because of the unavoidable diffuse operative and postoperative hemorrhage from decorticated bone surfaces in the region of the arthrodesis This contrasts with the surgical technique used for hemipelvectomy which has practically no effect on the nitrogen metabolism Case 3 *with no postoperative elevation of the nitrogen* excretion, is a good demonstration of this

Two of the orthopedic cases (cases 4 and 5) were immobilized in a large hip plaster for two months after the operation In spite of this the postoperative catabolism was equally large in some of the abdomi

nal cases that were mobilized much earlier This indicates that it is not only the degrees of postoperative muscular immobilization that is responsible for the metabolic change

The study supports the view that the postoperative intestinal function is related to the degree of postoperative catabolism Those patients who received food per os right from the start displayed a smaller metabolic reaction than those who received parenteral nutrition Cases 8–12 could not take food per os for 3–4 days during which time they received aminosol® One cannot rule out the possibility that part of the marked excretion of nitrogen in these cases may have been due to the complete breakdown of the amino acids administered without these being used for protein synthesis

The excretion of potassium returned to normal much sooner than the excretion of nitrogen which agrees with previous postoperative observations of this relationship (*Moore, Boling et al* 1955) The significant correlation between potassium excretion and nitrogen excretion shows that the former is dependent on the size of the surgical trauma

Elevated S OCT has been observed 4–7 days after operations (*Brohult* 1967) burn injuries (*Reichard et al* 1963) and irradiation of malignant tumours (*Brohult* 1968b) Tissue catabolism is common to all these three states Experiments on the rat have shown that the content of OCT in the liver rises in all states that involve an increased breakdown of proteins and an increased production of urea (*Schimke* 1963) Individuals given a protein rich diet for one week displayed an elevated S OCT during the first 24 hours after returning to a normal diet (*Brohult* 1968a) This suggests that S OCT rises when protein catabolism and urea synthesis start to decline so that OCT is no longer required to the same extent in the liver S OCT started to rise in the operated patients at the same time as catabolism changed to anabolism This may represent the same mechanism as for the protein rich diet *i e* the liver gets rid of the OCT that is synthesized in connection with the elevated protein catabolism The elevation of S OCT after 4–7 days thus seems to be a measure of the postoperative tissue catabolism This view is also supported by the significant correlation between the postoperative increase in nitrogen excretion and the elevation of S OCT after 4–7 days

The postoperative nitrogen excretion in the abdominal patients is of the same order as that observed during a protein rich diet One might expect the functional elevation of S-OCT to be equally marked in both cases but this is not so S OCT tripled after a protein rich diet (*Bro*

hult 1968a) whereas many of the abdominal cases displayed a tenfold rise 1–7 days after the operation. This does not necessarily contradict the theory that the elevation of S-OCT is a result of the liver getting rid of the OCT that becomes superfluous when protein catabolism declines. Other factors may be involved as well. The lysosome activity and the mitochondrial permeability may thus be different in the two conditions, one of which concerns healthy subjects given exogenous protein, the other patients in a catabolic phase who break down the protein in their body.

The significant correlation between the postoperative increase in 17-hydroxycorticosteroid excretion and the elevation of S-OCT after 1–7 days is probably due to both variables being dependent in different ways on the size of surgical trauma. The steroids cannot have elicited the rise in S-OCT by themselves because injections of 90 IE cortrophin® in healthy subjects did not elicit any such rise even though the suprarenal cortex was presumably stimulated to the maximum extent (*Brohult* 1968b).

The question remains whether a temporary, undetected liver hypoxia during the operation or a slight hepatotoxic effect of an anesthetic was responsible for the rise in S-OCT. Were this the case, however, the rise should have appeared immediately after or within 24 hours of the operation since hypovolaemic shock (*Brohult & Gillquist* 1968a), a temporary drop in blood pressure during spinal anesthesia (*Brohult & Gillquist* 1968b) and hepatotoxic substances such as carbon tetrachloride (*Reichard* 1962) elicit rises in S-OCT after only 24 hours. It has also been shown that uncomplicated halothane anesthesia without an operation does not give rise to any elevation of S-OCT (*Brohult & Gillquist* 1968b). Since no complications occurred in any of the present anesthesias and operations, an influence on the liver from such factors can be ruled out.

S-OCT thus seems to be a useful indicator of the metabolic trauma after an operation or some other form of strain on the organism. One should be careful not to jump to conclusions however, and make allowance for other factors, chiefly the status of the liver, since even a mild liver injury can elicit a high S-OCT.

SUMMARY

The metabolic reaction after 7 skeletal operations of different magnitude was compared with the reaction after 7 abdominal operations also of different degree. The nitrogen excretion during the first 24

hours was significantly lower in the orthopedic than in the abdominal cases Both groups showed a significant increase in S OCT 4–7 days after the operation this was also significantly correlated to the post operative increase in the excretion (per m body surface and 24 hours) of nitrogen potassium and 17 hydroxycorticosteroids All these variables seem to reflect the degree of metabolic trauma The increase in S OCT 4–7 days after the operation may be due to release of the OCT synthesized in the liver during the catabolic phase

ACKNOWLEDGEMENT

The study was supported by grants from the Stockholm County Council Stockholm Sweden and Carl Berthel Nathorst foundation Stockholm Sweden

REFERENCES

Barnes R. B Richardson D., Berry J W & Hood R. L. (1945) Flamephotometry A rapid analytical procedure *Ind Eng Chem Anal Ed* 17 605

Beckman V., Brohult J & Reichard H (1966) Elevations of liver enzyme activities in serum after halothane ether and spinal anaesthesia *Acta Anaesth Scand* 10 53

Birke G Diczfalusy E & Plantin L O (1958) Assessment of functional capacity of the adrenal cortex I Establishment of the normal values *J Clin Endocrin* 18 736

Blocker T G jr., Lewin W C Nowinski W W Lewis S R & Blocker V (1955) Nutrition studies in the severe burned. *Ann Surg* 141 589

Brohult J (1967) Liver reaction after halothane and diethylether anaesthesia. *Acta Anaesth Scand* 11 201

Brohult J (1968a) Effects of high protein and low protein diets on ornithine carbamoyl transferase activity in human serum (S OCT) *Acta Med Scand* (in press)

Brohult J (1968b) Serum ornithine carbamoyl transferase activity (S OCT) after irradiation of malignant tumours and after administration of ACTH *Acta Med Scand* (in press)

Brohult J & Gillquist J (1968a) Serum enzyme levels as a measure of liver reaction after hypovolaemic shock and operation in man *Acta Chir Scand* In press.

Brohult, J & Gillquist J (1968b) The effect of halothane anaesthesia and spinal anaesthesia with and without systolic blood pressure fall on serum ornithine carbamoyl transferase activity in man *Acta Chir Scand* In press

Cuthbertson D P (1945) The physiology of convalescence after injury Brit Med Bull 3 96

Dixon J D & Massey F J (1957) Introduction to statistical analysis McGraw Hill Book Comp Inc New York.

Hiller A Plazin J & Van Slyke, D D (1948) A study of conditions for Kjelldahl determination of nitrogen in proteins Description of methods with mercury as catalyst and titrimetric and gasometric measurements of the ammonia formed *J Biol Chem* 176 1401

Holden W D Krieger H Levey S & Abbott W E (1957) The effect of nutrition on nitrogen metabolism in the surgical patient. Ann Surg 146 563
Howard J G (1945) Protein metabolism during convalescence after trauma AMA Arch surg 50 166
Jungner I & Jungner G (1960) Disturbances in nitrogen metabolism in the acute stage of paralytic poliomyelitis Acta med scand 168 169
Krieger H Abbott W E Levey S Babb L L & Holder, W D (1954) Metabolic alterations in surgical patients Surgery 36 580
Moore F D & Ball M R (1952) The metabolic response to surgery (No 132 Amer Lect series) Springfield Ill., CC. Thomas
Moore F D Steenburg R W Ball M R Wilson G M & Myrden J A (1955) Studies in surgical endocrinology I The urinary excretion of 17 hydroxycorticosteroids and associated metabolic changes in tissue trauma of varying severity and bone trauma Ann Surg 141 145
Moore F D Boling E A Ditmore H B Jr Sicular A Teterich J E Ellison Hove S J & Ball M R (1955) Body sodium and potassium Metabolism 4 379
Moore F D (1959) Metabolic care of surgical patient. W B Saunders Company Philadelphia & London page 32-33 Idem page 126
Nilsonne U Hjelmstedt A & Hakelius A (1968) Surgical problems in hemipelvectomy Acta orthoped Scand 39 161
Reichard H (1962) Studies on ornithine carbamoyl transferase activity in blood serum Acta Med Scand Suppl 390
Reichard H Liljedahl S O & Birke G (1963) Serum activity of ornithine carbamoyl transferase and transaminases in severe burns Acta Chir Scand 126 43
Reichard H (1964) Determination of ornithine carbamoyl transferase in serum. J Lab clin Med 63 1061
Robert S (1953) The influence of the adrenal cortex on mobilization of tissue protein J Biol Chem 200 77
Schimke R. T (1963) Studies on factors affecting the levels of urea cycle enzymes in rat liver J Biol Chem 238 1012
Walshe J M (1953) Disturbances of aminoacid metabolism following liver injury Quart J Med Oxford 22 483
Wetterfors J (1965) Albumin Acta Med Scand Suppl 430

Acta orthop Scandinav 40 429–447 1969

Orthopaedic Clinic (Head Professor S Friberg) Karolinska Institutet
Stockholm Sweden

HOMOLOGOUS JOINT TRANSPLANTATION IN MAN

Ulf Nilsonne

Received 24 iii 68

Complicated problems of reconstruction are involved in the resection of all or part of a joint One solution is to replace the resultant defects with artificial material as is done for instance with a metal endo prosthesis in hip arthroplasty The disadvantage here is that since true union is ruled out the mechanical stability will depend upon the extent to which the bone tissue tolerates the foreign material In the case of a major resection it may be difficult or impossible to design a functional endoprothesis to fill in the defect This makes it desirable to look for a more biological solution One possibility that presents itself is substitution with homologous tissue i e with a homograft

Experiments and clinical attempts to perform homologous joint transplantation have been performed ever since the turn of the century (for detailed historical surveys see Chase & Herndon 1955 Woodruff 1960) Pinskij is thus quoted by Volkov (1966) as being the first to have performed such transplantations on sheep and dogs in 1893 though without obtaining stable union of the graft A large number of whole and half joint transplantations were performed by H Judet (1908) and others generally on the rabbit The transplant was re moved with or without the joint capsule and was implanted either subcutaneously or in its physiological location Comparisons were made with autologous transplants moved in a similar way The results proved contradictory Some of the homografts united properly but most of them degenerated rapidly and were resorbed Union was noted on the other hand for a large proportion of the autologous transplants and there was general agreement that these were preferable to the homograft Herndon & Chase (1952) made extensive studies of whole knee joint graft in the dog using both autologous and homologous transplants They found primary union of both types of graft with good functional results after observation times of up to two years but the

homografts subsequently degenerated and ultimately disintegrated entirely putting an end to the joint function

Homologous joint transplantation in man was first performed by Lexer in 1907 He transferred the graft straight from the donor without any special preservative measures The grafts were obtained at amputation or from recently deceased individuals In a summary published in 1925 Lexer reports having performed 23 whole joint and 11 half joint transplantations most of them involving the knee joint He also reports a permanent cure in twelve of the whole joint transplantations However, the cases with a long observation time displayed degenerative changes and even though the joint function was good the roentgenogram was reminiscent of osteoarthritis Histological studies on two of Lexer s whole knee joint transplantations were made by Bürkle de la Camp (1929) 14 and 16 years respectively after the operation He found for instance that the normal articular cartilage had been entirely replaced by fibrous tissue and that the intra articular ligaments and menisci had disappeared The tissue in the articular end of the bones was viable and normal in appearance All the half joint transplantations united without complications according to Lexer and gave a satisfactory joint function though in the long run mild osteoarthritis developed in the operated joint in these cases as well

Lexer s work is truly epoch making Even though the clinical follow up is not always clearly documented several of his cases must unquestionably be described as functionally excellent It is therefore surprising that the method was adopted by so few of his contemporaries and successors Apart from a few isolated cases (May 1942 Capurro & Pedemonte 1953) it is only during the past decade that homologous joint transplantation has been taken up once more

The modern method utilizes bone banks the joint transplant being kept in a frozen state until it is to be implanted

The conventional temperature for a bone bank is −15° to −20° C. Ottolenghi (1966) and Parrish (1966) have each reported seven cases of massive homologous half joint transplantations in the reconstruction of defects after the resection of skeletal tumours A complete femur was transplanted in one case Bony union was noted in all cases but there were varying degrees of partial resorption of bone and/or necrosis of the articular cartilage Large homografts have been used in similar cases by Merle d Aubingné et al (1966) In their reconstructions however these authors generally aimed at arthrodesis and consequently they have seldom used articular transplants

Important contributions to the development of homologous joint transplantation have been made by Russian researchers in recent years After extensive experimental studies on the dog Imamaliev (1964) demonstrated that a transplantation was more likely to be successful if the transplant was pre treated with a considerably lower temperature than that used in an ordinary bone bank He found that the optimal conditions for storage of the homograft were —70 C for 24 hours followed by —20 C for one month

This technique was adapted to clinical conditions by Volkov who has reported (1966) the largest series of homologous joint transplantations in man to date with a maximum observation time of 7 years Half joint transplantations had been performed in 80 cases with an excellent result in 47 *ie* complete anatomical restoration of the joint region as well as normal mobility and weight bearing by the joint Bony union was achieved in a further 24 cases but later there was arthrosis with impaired joint mobility In the remaining 9 cases the result was poor with disintegration of the transplant which had to be resected in some cases

Volkov s report also includes 25 homologous whole joint transplantations (20 knee joints and 5 hip joints) Since these cases had been observed for less than 4 years it was considered too early to present any conclusions This group also clearly includes cases with "rapid bony union satisfactory mobility and reossification of the graft without loss of shape

After personal studies with Volkov (Nilsonne 1967) I was convinced that homologous joint transplantation represents a valuable method for the reconstruction of large bone joint defects The present paper reports four cases of my own in which the therapy has been based upon the Russian method

METHODS

The transplants were obtained from persons who had died of other causes than malignant tumour or an infectious disease The suitable part of the skeleton (from the femur in all cases) was removed under normal, sterile surgical conditions less than 6 hours *post mortem* Soft tissues were carefully scraped away from the diaphysis and the joint capsule was resected. The cruciate and collateral ligaments were retained in knee joint grafts but not the round ligament in the case of grafts from the head of the femur

The transplant used in Case 1 was sterilized in β propiolactone immediately after it had been removed from the donor It was then placed in the bone bank and stored t —70 C (no deep freezer being available at that time) The transplants that were

Figure 1 A and 1 B Roentgenograms of parosteal osteo sarcoma in distal femur frontal and lateral projections respectively

Figure 1 C Arteriogram showing posterior dislocation of the popliteal artery by the tumour



taken later were placed in sterile plastic boxes which were then sealed and placed in a deep freezer (Industrial Products Laboratory Freezer JP 275) at —70 C and kept at this temperature for 24–48 hours The temperature in the freezer was then raised to —20 C and the transplant was stored there for 1–4 weeks before use The transplant was removed from the freezer about 1 hour before the calculated time of implantation and thawed in 37 C physiological saline solution to which a large dose of penicillin had been added Bacteriological tests from the graft were negative both before and after the freeze treatment

The surgical technique varied from case to case and is described in the following case reports

MATERIAL AND RESULTS

Four cases of primary bone tumour were operated with homologous joint transplantation In each case the conventional alternative to this reconstruction was amputation or exarticulation in one case even hemipelvectomy

Case 1

Woman 20 years of age Occasional slight pains in the right popliteal fossa for about one year but it was only 14 days before admittance to the hospital that the



Figure 2 Resected distal femur the tumour clearly visible behind and above the condyles

patient had noticed a tumour there At the clinical examination a bony resistance the size of a tangarine was palpated in the right popliteal fossa Roentgenography showed a well defined periostal tumour issuing from the popliteal surface of the femur Osteolytic destruction was observed in the spongy bone of the femoral condyle where the anterior cortex was thin Angiography demonstrated dorsal dislocation of the popliteal artery by the tumour but no distinctly pathological vessels were seen (Figures 1a–1c) Biopsy showed that the tumour was a *parosteal osteosarcoma*

Since the tumour was chiefly locally malignant it was decided to avoid a femoral amputation and instead a radical local resection was planned followed by reconstruction with a homologous half joint graft At operation on 18 April 1966 the clearly encapsulated tumour was found to be growing expansively in the soft tissues Vessels and nerves in the popliteal fossa were not engaged and could be moved to one side After dissection the femur was sawn through 16 cm proximal of the knee joint The bone here was macroscopically tumour free and this was verified by frozen section biopsy The musculature was freed from the distal femur the capsule of the knee joint was cut ventrally and laterally at the level of the epicondyles but was extirpated dorsally and the cruciate and collateral ligaments were severed at their attachments to the femur The block resection of the distal femur including the tumour was completed after further soft tissue dissection (Figure 2) The graft was now fitted into the defect and fixed to the patient's femur with two 6 hole plates (Figure 3a) The cruciate and collateral ligaments on the graft were sutured side by side to the corresponding structures in the patient

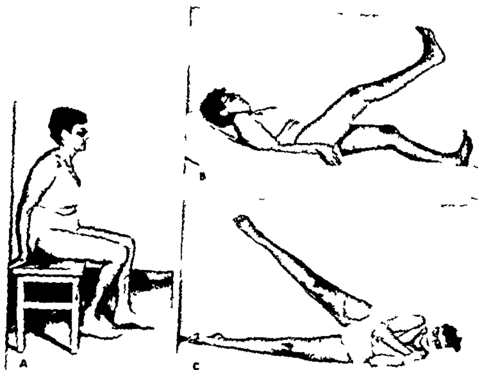


Figure 7 Case 2 Photographs showing the ranges of active and passive mobility in the hip and knee joint of the operated leg (right) 13 months after the operation

active abduction in the hip joint and the passive rotational mobility is normal (Figure 7)

A subfebrile temperature characterized the first two postoperative weeks after which the temperature has been normal The sedimentation rate has been normal throughout During the first two weeks there was also an anaemia as well as reduction of total proteins in serum to 5 5 per cent and the albumin fraction to 44 3 per cent These parameters soon returned to normal after blood transfusions and intravenous administration of albumin and they have subsequently remained within normal limits Electrophoretic controls showed elevated α globulins during the first weeks followed by a return to normal levels There was no rise in the γ globulin fraction The patient s general condition has been entirely unaffected throughout the follow up period

Case 3

Woman 42 years of age Pains and a swelling in the left knee that gradually grew in the 3 months before admission X ray examination showed a cystic well defined destruction in the lateral femoral condyle (Figure 8a) Biopsy gave the diagnosis *giant cell tumour grade II–III* After treatment with curettage the cavity was filled with heterologous bone transplants (Kieler Knochenspan) (Figure 8b) Bony union seemed to be taking place at first but after about one year there were roentgenological signs of local recurrence of the tumour (Figure 8c) Another biopsy



Figure 8 A Giant-cell tumour in the lateral condyle of the femur
Figure 8 B After curettage and filling of the cavity with heterologous bone
Figure 8 C. Recurrence of tumour 1 year later



Figure 9 A After resection of the lateral distal part of the femur the homograft being fixed in its bed
Figure 9 B 4 months after the transplantation.
Figure 9 C. Consolidation 10 months after the transplantation

indicated that the giant cell tumour still belonged to grade II–III. It was therefore considered justifiable to treat the tumour by local resection.

At operation on 23 April 1967 it was found that the tumour had penetrated the cortex dorsally and laterally but that it was growing expansively with a well



Figure 10 A Central fibrosarcoma in the distal femur

Figure 10 B and C The distal femur has been resected and a homograft put in place The transplant is fixed to the host femur by Rush pins stability in the region of osteosynthesis also being secured by step cut osteotomies

defined capsule This made it feasible to resect the whole of the lateral femoral condyle including the tumour The medial plane of resection was placed next to the attachment of the cruciate ligament the proximal 10 cm from the articular surface of the condyle The posterior cruciate ligament and the lateral collateral ligam nt were sacrificed The defect was filled with a homograft which was fixed with screws (Figures 9a) It was not possible to reconstruct the joint capsule

Postoperatively the entire leg was kept in plaster for 4 5 months after which knee mobility was exercised without weight bearing X ray examinations showed progressive bony union of the graft After ten months the union appeared to have consolidated (Figures 9b and c) and weight bearing was started The knee joint is completely stable with an active range of movement of 175–140 There is no pain on weight bearing

The immediate postoperative reaction was moderate with a slight temporary rise in temperature and an increase in the sedimentation rate Total proteins in serum were normal but the albumin fraction fell to 54 7 per cent and α and γ globulin rose to 10 0 per cent and 20 3 per cent respectively during the first weeks All these parameters subsequently returned to normal spontaneously The patient s general condition was excellent throughout

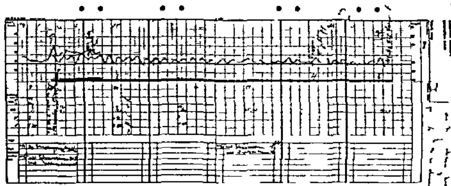


Figure 11 Temperature chart showing the mild reaction after homografting

Case 4

Woman 37 years of age Diffuse moderate ache in the left knee for about 5 months More severe pains after a fall from a bicyle led to an X ray examination An irregular patchy destruction was observed in the distal femur most pronounced in the lateral condyle (Figure 10a) Biopsy showed that the change was due to a *central fibrosarcoma* of low malignancy (tissue resembling that in desmoplastic fibroma of bone was demonstrated in parts of the tumour)

At operation on 21 September 1967 block resection of the distal femur was performed 16 5 cm proximal of the articular surfaces of the femoral condyle The re ection was macroscopically radical and this was verified by histopathological examination The defect was filled with a homologous half joint transplant that was fixed to the host femur with two Rush pins (Figures 10b and c) The surfaces of the osteosynthesis were shaped as for a Z shaped osteotomy Autologous cortical bone grafts from the femur were placed next to the region of osteosynthesis In the knee joint the cruciate and collateral ligaments on the graft were sutured side by side to those of the host The joint capsule was sutured to the transplant The entire leg was encased in plaster after the operation and this treatment is still in progress An X ray examination 1 February 1968 showed signs of a periostal callus

The postoperative course was entirely uneventful There was hardly any rise in either the body temperature or in the sedimentation rate (Figure 11) There was no anaemia and total proteins in serum were normal The albumin fraction dropped temporarily to 51 ? per cent at the same time as α_2 globulin rose to 11 0 per cent and γ globulin to 19 0 per cent after which normal values were recorded The patient s general condition was entirely unaffected

IMMUNOLOGIC STUDIES

Immunologic tests were conducted in Cases 1 and 2 nineteen and ten months respectively after the transplantation in collaboration with the Research Laboratory Surgical Clinic at Serafimerlasarettet The test

was designed to tell whether the host's lymphocytes had become immune to the homograft Using a method reported by Coulson & Chalmers (1964), lymphocytes were isolated from peripheral venous blood from the patients The lymphocytes were then placed on monolayer cultures of five different human fibroblasts according to Moller et al (1967) In no case did the lymphocytes appear to have any cytotoxic effect on the different fibroblasts

DISCUSSION

The results in these cases of homologous joint transplantation must be regarded as preliminary because the observation time is still so short The favourable findings to date nevertheless make it worth reporting the observations of a theoretical and practical nature that are associated with the method employed

The essential innovation in the procedure concerns the pre treatment of the homograft The deep-freeze technique seems to be a prerequisite for a successful transplantation Lexer and his contemporaries who generally performed direct transplantation between donor and host admittedly achieved surprisingly good bony union in some cases Degenerative changes in the graft frequently appeared quite soon however which is probably why the method was abandoned In contrast to this the Russian technique by which the transplant is frozen at —70 has resulted in good union between the homograft and the host bone in a majority of both the experimental (Imamaliev) and the clinical (Volkov) cases The transplants in Cases 2 3 and 4 in the present series were pre treated according to the Russian technique and the absence of any postoperative reaction was analogous to the results of the authors cited

Theoretically too a temperature of —70° should be suitable for preserving massive bone joint transplants It has thus been shown that at —70 the tissue fluids form ice crystal *intracellularly* whereas at —20 they chiefly form *extracellular* ice crystals (Meryman 1957) The shorter the time taken to freeze the specimen the more the intra cellular reaction will predominate The capacity of the present freezing unit is such that the specimen are calculated to have been frozen to a homogenous temperature of —70 in about one hour This treatment probably resulted in the definite destruction of all the cells in the transplant

This assumption is supported by the immunologic studies, which

showed that the host's lymphocytes had no cytotoxic effect on the fibroblasts tested It must be admitted however that these tests could not be made with fibroblasts from the specific donor of the graft On the other hand it seems reasonable to draw a parallel with patients receiving homologous skin grafts These patients lymphocytes thus have a cytotoxic effect on most of the fibroblasts tested which suggests that there is a high incidence of cross reactivity One would expect to find the same high incidence of cross reactions regardless of the type of tissue transplanted since the transplantation antigens are probably represented on all nucleated cells The negative results in Cases 1 and 2 suggest that the patients had not become immune probably because the graft did not contain viable cells at the time of the operation

Another consequence of freezing the transplants is an effective sterilization of them This was confirmed by the negative bacteriological tests after the transplants had thawed as well as by the aseptic course in Cases 2 3 and 4 Intensive postoperative antibiotic treatment is nevertheless called for in view of the length of the operation which was about 6 hours for the most massive transplantation The conservation technique employed in Case 1 (sterilization with β propriolactone and storage at —20) must be considered in connection with the postoperative infection Sterilization of vascular grafts heart valves bone grafts etc with β propriolactone is recommended by Lo Grippo et al (1957) Investigations concerning this clinic's conventional bone bank which is run at —20 (Hult 1950 Nilsonne 1963) have not revealed any appreciable complications in the form of infection It is thus unlikely that the bone-bank technique was responsible for the local infection in Case 1 Contamination of the wound in some other way was probably responsible for this

The surgical trauma involved in a joint transplantation can be classified as moderate The general condition of all the patients was thus very little affected in the postoperative phase The typical postoperative effect comprised slight anaemia moderately elevated sedimentation rate depressed albumin level and a rise in α_2 globulin and γ globulin These reactions were transient in Cases 2 3 and 4 the value returning to normal a few weeks after the operation These findings are similar to the results reported by Asén et al (1965) for surgical trauma in the treatment of fractures and non union of the lower leg The metabolic reactions in the present cases are thus not specific for homologous joint transplantations The more prolonged disturbances registered in Case 1 are ascribable to the infection

As pointed out above the homograft consists of dead tissue There is no viability to start with either in the osteoid tissue or in the articular hyaline cartilage The graft must be absorbed reconstructed and incorporated by the invasion of host tissue This process was followed on the X ray from the callus formation in the region of osteosynthesis At the same time it is remarkable how well the homograft in Cases 2 3 and 4 retained not only its outer shape throughout the process but also the typical trabecular bone structure in the meta and epiphyses It has not been considered necessary to make bone biopsies for histological checks in these cases because the X rays indicate that creeping substitution of the graft s osteoid component is taking place Neither have histological studies been made on the cartilaginous component the articular cartilage for fear of disturbing the intra articular adaption No roentgenological change has been observed in the structure of the transplanted joint components nor are there any signs of osteoarthritis (except in Case 1 in which osteomyelitis and septic arthritis have developed) The observation time in Cases 2, 3 and 4 is still short (max 13 months), however, and more definite conclusions must await the result of prolonged functional utilization of the homograft

The most noteworthy bone biological reaction occurred in Case 1 Callus formation was poor and a clinically manifest osteomyelitis developed with pronounced macroscopic destruction of the graft Even so biopsies from the graft 12 and 16 months after the transplantation showed histological signs of vital bone tissue In spite of the osteomyelitis and the non union between the host bone and the graft the latter was being transformed in a viable direction This was most probably the result of the graft being invaded by vessels from surrounding tissue which thereby created channels for osteoid tissue A healing mechanism of this type has been demonstrated in experimental fractures by Göthman (1961) The observation emphasizes the importance of further studies on the induction of osteogenesis

In choosing a method of fixation to promote osteosynthesis between the graft and the host bone consideration must be paid to the need for stability as well as the creation of optimal conditions for callus formation In Case 2 this problem was resolved by reaming the medullary cavity until its circumference was exactly the same in the host bone and the graft exceedingly rigid fixation was then achieved with the medullary nail In the other cases compression was achieved with screws or Rush pins The importance of good internal fixation is also heavily emphasized by Volkov who recommends step cut osteotomies

in the region of osteosynthesis as an extra precaution against lateral dislocation This was done in Case 4 The contact surfaces are larger with this type of osteotomy and callus formation is accordingly facilitated The addition of autologous bone grafts to the region of osteosynthesis in Cases 2 and 4 should theoretically stimulate callus formation still further

Stable internal fixation is also essential for early exercise of the operated and the neighbouring joints It may be possible to start such exercises sooner after the operation than has been attempted to date A good muscle pump improves the local circulation which is important for incorporation of the homograft Restitution of the graft takes a long time and the union must be sufficiently stable before weight bearing can be permitted Volkov and Ottolenghi recommend total non weight bearing for 10–12 months This practice has been adopted in the present cases with good results to date

It is still too early to assess the importance of reconstructing the ligamentary apparatus This was done in the knee joint in Cases 1 and 4 If normal or almost normal joint mobility is achieved postoperatively however some ligamentary function will presumably be required to ensure stability in the joint

A central question in the discussion of homologous joint transplantation concerns the indication for this operation From a simple mechanical point of view the indication is a desire to substitute a bone joint defect In other words it is a question of performing an arthroplasty with biological material in order to achieve true bony union Defects that can be treated in this way may arise for instance after radical resection of primary skeletal tumours located close to a joint Five of Ottolenghi s seven cases thus concerned giant cell tumours and Volkov also regards skeletal tumours as one of the main indications for homologous joint transplantation Volkov s other indications include skeletal defects after osteomyelitis tuberculosis or trauma as well as dysplasia of joint components Merle d Aubigné et al recommended massive homografts in the surgical treatment of giant cell tumours parosteal osteosarcoma and certain types of chondrosarcoma

In the present series of homologous joint transplantation Case 1 had a parosteal osteosarcoma Case 2 a well differentiated chondrosarcoma Case 3 a giant cell tumour and Case 4 a central fibrosarcoma

In the case of parosteal osteosarcoma it seems to be agreed that radical resection is the method of choice (Copeland 1965 McKenna et al 1966) The present case of chondrosarcoma most closely represented

a well differentiated peripheral chondrosarcoma, for which radical resection is also justified (Lichtenstein 1965 McKenna et al Dahlin 1967) Local resection has been recommended if possible in cases of giant cell tumour (Sherman 1965 Lichtenstein 1965) The proximity of a joint however often leads to curettage being tried first but the frequency of recurrence is high The possibility of joint transplantation makes resection a considerably more adequate measure In the case of central fibrosarcoma it is not certain whether amputation is necessary or whether local resection is sufficient In Case 4 the fibrosarcoma was well differentiated, which justified the treatment with block resection (Jaffe 1965 McKenna et al 1966)

There were thus clear indications for local surgery in these four cases Such cases would previously have been treated with amputation for want of suitable substitution material The use of a homologous joint transplantation makes it possible to avoid disfiguring measures without endangering the biological principles for treatment of the tumour This opens up new possibilities for the treatment of primary bone tumours

SUMMARY

Four cases of homologous joint transplantation in man are presented The indication for this surgical treatment was the presence of a primary bone tumour which was resected together with the articular end and part of the shaft in one case of the proximal femur in three cases of the distal The observation time is still short In two cases there was complete roentgenological and clinical union within 10–12 months The patients are allowed full weight bearing which is not painful and is performed with good active and passive mobility in the operated joints The theoretical technical and surgical problems in homografting of bone and joint components are described and discussed

REFERENCES

Burkle H de la Camp (1929) Die Untersuchungsbefunde von zwei homoplastisch verpflantzen Kniegelenken Z Chir 217 109

Capurro R G & Pedemonte P U (1953) Hydatid cyst of the femur Total removal of the femur and replacement by a complete cadaver femur J Bone Jt Surg 35 B 84

Chase S W & Herndon C H (1955) The fate of autogenous and homogenous bone grafts J Bone Jt Surg 37 A 809

Copeland M (1965) Parosteal osteoma Differential diagnosis and treatment. In Tumors of bone and soft tissue Year Book Medical Publ., Chicago

Coulson A S & Chalmers D G (1964) Separation of viable lymphocytes from human blood *Lancet* I 468

Dahlin D C (1967) *Bone tumours* Charles C Thomas Publ Springfield Illinois

Gothman L (1961) Vascular reactions in experimental fractures *Acta chir scand* Suppl. 284

Herndon C H & Chase S W (1952) Experimental studies in the transplantation of whole joints *J Bone Jt Surg* 34 A 564

Hult L (1950) Some experiences with a bone bank *Acta orthop scand* 19 [illegible]

Imamaliev A (1964) *Homologous joint transplantation* Edit Medicina [illegible] (In Russian)

Jaffe H L (1965) Fibrosarcoma of bone and bone involvement by direct extension of soft part sarcoma. In *Tumours of bone and soft tissue* Year Book Med Publ Chicago

Judet H (1908) Essai sur la greffe des tissues articulaires *Comp Rend Acad Sc Paris* 146 193 600

Acta orthop Scandinav 40 448–460 1969

Orthopedic Clinic (Head Professor S Friberg) Karolinska Institutet and the Department of Radiopathology (Head Professor L Santesson) Karolinska Sjukhuset Stockholm Sweden

PIGMENTED VILLONODULAR SYNOVITIS OF JOINTS

Histological and Clinical Problems in Diagnosis

ULF NILSONNE & GUNNAR MOBERGER

Received 29 iii 68

Pigmented villonodular synovitis is a benign lesion located in joints tendon sheaths or bursae The characteristics of the lesion and its identity in relation to other pathological synovial states were described by Jaffe Lichtenstein & Sutro in 1941 Previously and even nowadays however several other diagnostic terms are encountered many of them confusing e g xanthoma xanthogranuloma giant cell tumor benign giant cell synovioma fibrohemosideric sarcoma, polymorpho cellular tumor of the synovial membrane All these names refer in various ways to the complex histological picture Jaffe et al combined the various components into a single entity with the microscopical characteristics of pronounced hyperplasia and proliferation of synovial cells and undifferentiated connective tissue cells in the synovial membrane The cells contain varying amounts of hemosiderin pigment and/or lipid granules Multinuclear giant cells are also encountered in varying numbers Macroscopically the lesion takes the form of nodular tumorous reddish brown or yellowish brown excrescenses of the synovial membrane usually diffuse in a joint but more localized in a tendon sheath

Lesions of this type are fairly common in tendon sheaths of the fingers and toes Pigmented villonodular synovitis of joints on the other hand is a rare complaint The lesion is always monoarticular the knee joint being by far the most common location In a review of the literature Smith & Pugh (1962) found 202 published cases of pigmented villonodular synovitis (including seventeen of their own) with the following locations knee joint 164 ankle joint 14 hip joint 12 tarsal joints 4 carpal joints 4 elbow joint 3 and shoulder joint 1 case Most individual reports comprise only a few cases Larger series have

been published for instance by Jaffe (1958) 25 cases Smith & Pugh (1962) 17 cases Nilsonne (1966) 16 cases De Santo & Wilson (1939) 9 cases Wright (1951) 8 cases and McMaster (1960) 6 cases

As the majority of authors have pointed out it may be difficult to make a differential diagnosis between pigmented villonodular synovitis and other lesions particularly synovial sarcoma An incorrect diagnosis may result in the wrong treatment The consequences will be particularly serious if a pigmented villonodular synovitis which is a benign lesion is treated as a malignant disease The purpose of the present paper is therefore to analyze the histological and clinical criteria for the diagnosis pigmented villonodular synovitis

MATERIAL

The material comprises 29 cases of pigmented villonodular synovitis of a joint. This was the primary diagnosis in 14 of the cases the others have been reclassified. The primary diagnosis was thus synovial sarcoma in 10 nine of which come from a basic material of one hundred and sixty synovial tumors that was used by Moberger Nilsonne & Friberg Jr (1968) for a study of ninety cases of synovial sarcoma The primary diagnosis in 3 other cases was chronic unspecific synovitis and in 2 cases giant-cell xanthoma

The distributions by sex age and location are shown in Figure 1 The female male ratio was 20 9 All age groups are represented though more than half of the cases concern individuals between 20 and 50 years of age The knee joint was affected most often 19 cases whereas the hip joint was represented in 4 cases the ankle joint in 3 the wrist joint in 2 and the metatarsophangeal joint in 1 case

SURVEY OF CLINICAL CASES

Hip Joint, 4 Cases

Pain was the predominant symptom in pigmented villonodular synovitis located in the hip joint The pain emanated from deep in the groin

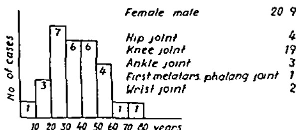


Figure 1 Distribution by sex age and localization of 29 cases of pigmented villonodular synovitis of joints

Acta orthop Scandinav 40 448-460 1969

Orthopedic Clinic (Head Professor S Friberg) Karolinska Institutet and the Department of Radiopathology (Head Professor L Santesson) Karolinska Sjukhuset Stockholm Sweden

PIGMENTED VILLONODULAR SYNOVITIS OF JOINTS

Histological and Clinical Problems in Diagnosis

ULF NILSONNE & GUNNAR MOBERGER

Received 29 iii 68

Pigmented villonodular synovitis is a benign lesion located in joints tendon sheaths or bursae The characteristics of the lesion and its identity in relation to other pathological synovial states were described by Jaffe Lichtenstein & Sutro in 1941 Previously and even nowadays however several other diagnostic terms are encountered many of them confusing *e g* xanthoma xanthogranuloma giant cell tumor benign giant cell synovioma fibrohemosideric sarcoma polymorpho cellular tumor of the synovial membrane All these names refer in various ways to the complex histological picture Jaffe et al combined the various components into a single entity with the microscopical characteristics of pronounced hyperplasia and proliferation of synovial cells and undifferentiated connective tissue cells in the synovial membrane The cells contain varying amounts of hemosiderin pigment and/or lipid granules Multinuclear giant cells are also encountered in varying numbers Macroscopically the lesion takes the form of nodular tumor ous reddish brown or yellowish brown excrescenses of the synovial membrane usually diffuse in a joint but more localized in a tendon sheath

Lesions of this type are fairly common in tendon sheaths of the fingers and toes Pigmented villonodular synovitis of joints on the other hand is a rare complaint The lesion is always monoarticular the knee joint being by far the most common location In a review of the literature Smith & Pugh (1962) found 202 published cases of pig mented villonodular synovitis (including seventeen of their own) with the following locations knee joint 164 ankle joint 14 hip joint 12 *tarsal joints 4 carpal joints 4 elbow joint 3* and shoulder joint 1 case Most individual reports comprise only a few cases Larger series have

Figure 9 Pigmented villonodular synovitis in the ankle joint Small cysts in the tibia (arrow) Slight soft tissue swelling distal to the lateral malleolus



At operation all the cases presented hyperplastic reddish brown hemorrhagic synovialis The changes were chiefly located to the supra tellar bursa in 2 cases and the semimembranosus bursa in another 2 whereas localized pedicled intra articular formations were found in 1 case The other cases presented a diffuse intra articular process

A primary histopathological diagnosis of synovial sarcoma was made on resected tissue in 5 cases

Ankle Joint, 3 Cases

In 2 of these cases a palpable resistance anterior to the joint was interpreted as a ganglion or tumor The third case had a swelling and tenderness on palpation just distal of the lateral malleolus In view of an early trauma this was thought to represent a ruptured ligament

The X ray examination showed normal conditions in 1 case and bony destruction of the articular ends as well as of the cuneiform bones in 1 case In the latter case arteriography demonstrated pathological vessels with arterio venous shunting In the supposedly post traumatic case the roentgenographic picture (Figure 9) demonstrated small cysts in the tibia and slight soft tissue swelling of the lateral part of the joint

A primary histopathological diagnosis of synovial sarcoma was made on resected tissue in 2 cases

First Metatarsophalangeal Joint, 1 Case

The symptom in this case was a tender resistance on the dorsal side of the first metatarsophalangeal joint Biopsy showed intra articular proliferation of reddish brown tissue The primary histopathological diagnosis was synovial sarcoma



Figure 10 Pigmented villonodular synovitis in the wrist joint showing small cysts in the capitate bone

Wrist Joint, 2 Cases

In both these cases a resistance on the dorsal side of the wrist joint was interpreted as a ganglion An X ray examination showed small cyst like changes in the capitate bone in one of these cases (Figure 10) The primary histopathological diagnosis was synovial sarcoma in both cases

EFFECTS OF ERRONEOUS PRIMARY DIAGNOSIS

As indicated above, an erroneous primary diagnosis of synovial sarcoma was made in 10 cases altogether This resulted in amputation in 5 of these cases at the thigh in two at the lower leg in three Two of the amputated patients were subsequently found to have been registered as having died from metastases of synovial sarcoma in both cases 7 years after the operation On reclassification, however it was found that the cause of death was primary lung cancer

In another 2 cases complications arose because irradiation therapy was given for the supposedly malignant process In one of these cases the patient incurred a pathological fracture of the distal femur A biopsy undertaken in connection with open reduction of the fracture showed necrotic osseous tissue Although the fracture ultimately healed the patient was permanently disabled In the other case a severe local skin reaction resulted in many years of discomfort from recurrent dermatitis

The remaining 3 cases also received local irradiation therapy but no complications materialized

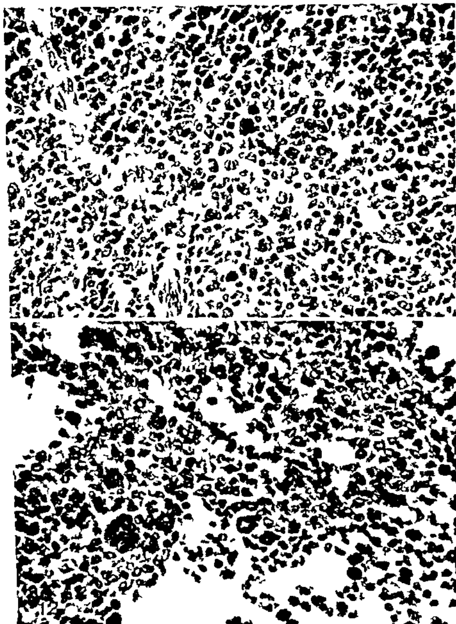


Figure 11 Pigmented villonodular synovitis Photomicrograph × 150 Granulomatous highly cellular proliferations with scattered multinucleated giant cells

Figure 12 Pigmented villonodular synovitis Photomicrograph × 400 Tendency to increased dissociation of individual cells and numerous multinucleated giant cells

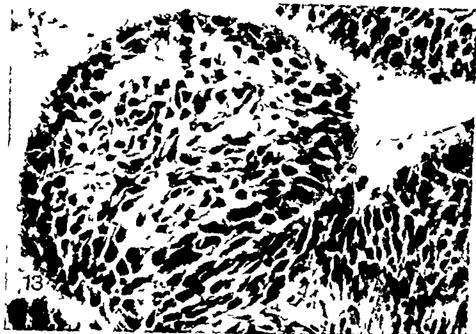


Figure 13 Pigmented villonodular synovitis Photomicrograph × 400 Marked proliferation of the synovial cells lining the surface of the synovial membrane

DIAGNOSTIC COMMENTS

Histology

Histologically the synovial tissue in pigmented villonodular synovitis is characterized by enlarged plump synovial excrescences bulging into the joint cavity Both these excrescences and the tissue of the joint capsule that encloses them present a process with an abundance of cells which in principle resembles the tissue of a hyperplastic granuloma The cell structure is reminiscent of that in so called giant cell tumors in tendon sheaths though the cells are usually considerably more numerous (Figure 11) This great cellularity means that the process is readily mistaken for a tumor The cell proliferation however is characterized by the presence of phagocytic elements many of them containing lipid granules and hemosiderin pigment The presence of numerous phagocytes of this type often in clusters is such a common phenomenon that the finding is of diagnostic importance There are also multinuclear giant cells (Lichtenstein 1955) of the so called foreign body type Another characteristic is the marked tendency to dissociation of the individual cells in the highly cellular process (Fig

ure 12) which distinguishes this from synovial sarcoma The number of lymphocytes varies but usually they account for only a small proportion of the cells

The highly variegated pattern of the abundantly cellular proliferation may make this deceptively like a pronounced cellular polymorphism The synovial lining cells frequently display a marked tendency to proliferation (Figure 13) and the zone of transition to the granulomatous process may be indefinite This may further strengthen the suspicion of a neoplastic process particularly as some degree of cell atypia may be displayed in the proliferations of synovial cells (Wright 1952 Geiler 1961) On the other hand the presence of giant cells hemosiderin pigment and dissociation tendencies are indicative criteria for the histological diagnosis There may be necrosis against the surfaces of the joint but the picture does not include specific inflammatory granulomatous tissue

CLINICAL ASPECTS

Pigmented villonodular synovitis can hardly be diagnosed from the clinical or the radiographic examination alone As indicated in the clinical survey above the first clinical diagnosis proposed is usually unspecific synovitis osteoarthritis or tumor

It used to be thought that the radiographic examination of these cases could simply show swelling of soft tissues as a sign of an excessive synovitis Bony involvement was held to point to a synovial sarcoma (Lewis 1947) As the number of published cases increased (Breimer & Freiberger 1958 McMaster 1960) it was found that skeletal changes may occur in pigmented villonodular synovitis as well Smith & Pugh (1962) for instance report that osseous changes are present in about half of the cases As demonstrated in the clinical survey of our cases the lesions often appear as well-defined single or multiple cystic cavities in the bone ends of the joint There may even be skeletal erosion suggestive of a malignant process especially in the hip joint

In the case of the knee joint a chronic or recurrent swelling *with* hemarthrosis but *without* trauma should suggest the possibility of a pigmented villonodular synovitis At exploration a good macroscopic sign is the reddish brown thickened and bearded appearance of the synovial membrane in an entirely intra articular lesion Synovial sarcomas on the other hand are almost always extra articular only 3

exceptions being found in a series of 90 by Moberger Nilsonne & Fri berg Jr (1968) Hemarthrosis and villous intra articular synovial excrescences with a brown pigmentation are thus very strong indi cations of a pigmented villonodular synovitis Conversely, a histo-pathological diagnosis of synovial sarcoma should be regarded with suspicion if the change is intra articular The preoperative assessment of the lesion in relation to the joint cavity may be facilitated by the use of arthrography cf Rein et al (1964) and some of the present cases The nodular synovitis may then appear as defects in the contrast pic ture of the joint whereas this would not be the case with an extra articular process

The radiographic picture in pigmented villonodular synovitis in the hip joint is characterized by multiple cysts in the acetabulum and the femoral head and neck The appearance may resemble osteoarthritis of the hip and there may also be similarities in the clinical symptoms In pigmented villonodular synovitis the cysts in the acetabulum are chiefly located in the medial and distal parts of the joint whereas in osteoarthritis they are usually located to the cranio lateral part Osteo arthritis involves deformation of the femoral head whereas the out line of this is generally unchanged in cases of pigmented villonodular synovitis These observations are in accordance with a report by Chung & Janes (1965)

The case illustrated in Fig 5 had the clinical and radiographic ap pearance of a septic arthritis and should be regarded as an unusual manifestation In some respects however it resembles a case pub-lished by Carr et al (1954), in which a large retroperitoneal synovial cyst originated from and was in open communication with the hip joint Arthrotomy revealed considerable villonodular distruction of all the articular components This description is identical with the findings at operation in our case except that here the joint capsule was enor mously distended This may represent an alternative outcome of an in creased intra articular pressure which in Carr s case resulted in her niation of the joint capsule

Arteriography was performed in two cases in the present series showing marked hypervascularity and pathological vessels in the lesional region Similar findings were reported by Rein et al in 1 case of pigmented villonodular synovitis of the knee joint The presence of pathological vessels however is an unreliable indication of malig nancy which should not be allowed to influence the pathologist s assess ment of tissue specimens

As far as pigmented villonodular synovitis in other joints than the knee and hip are concerned the number of cases is still too small to indicate the principles for clinical diagnosis The presence of the typical intra articular tissue described above and the appearance of cyst like bony changes in roentgenograms should however guard the diagnosis

DIAGNOSTIC CONCLUSIONS

Intra articular lesions particularly in the knee joint that present the macroscopic appearance of a hyperplastic villous synovial membrane with brown pigmentation should be suspected of representing pigmented villonodular synovitis The diagnosis can be confirmed on the following microscopic criteria cell rich, granulomatous process with variegated cells and the presence of multinuclear giant cells as well as (clusters of) phagocytes containing hemosiderin pigment The tendency towards differentiation of the individual cells in the cell proliferation may be a particularly important criterion in the differential *diagnosis with synovial sarcoma The great cellularity of the process* may deceive the less-experienced pathologist into interpreting the picture as that of a malignant tumor primarily a synovial sarcoma A histological study of 160 cases with the primary diagnosis of synovial tumor (Moberger Nilsonne & Friberg Jr) has shown that pigmented villonodular synovitis presents a characteristic cell picture In particular it may be noted that multinuclear giant cells do not occur in the malignant synovial tumors and that hemosiderin pigmented phagocytes only occur in extremely rare cases

SUMMARY

The histological and clinical criteria are presented for the diagnosis of pigmented villonodular synovitis of joints in a study of 29 cases of the lesion Special reference is made to the differential diagnosis with synovial sarcoma Emphasis must be placed on the necessity of close co-operation between the orthopedic surgeon the roentgenologist and the pathologist in the diagnostic evaluation of these cases

REFERENCES

Breimer Ch. W & Freiberger R. H (1958) Bone lesions associated with villonodular synovitis. *Amer J Roentgenol* 79 618

Carr Ch R Berley F V & Davis W C (1954) Pigmented villonodular synovitis of the hip joint *J Bone Jt Surg* *36 A* 1007

Chung S M K & Janes J M (1965) Diffuse pigmented villonodular synovitis of the hip joint. *J Bone Jt Surg* 47 A, 293

De Santo D & Wilson Ph D (1939) Xanthomatous tumors of joints *J Bone Jt Surg* 21 531

Geiler G (1961) *Die Synovialome* Springer Verlag Berlin.

Jaffe H L Lichtenstein L & Sutro C J (1941) Pigmented villonodular synovitis, bursitis and tenosynovitis *Arch Path* 31 731

Jaffe H L (1958) In *Tumors and tumorous conditions of the bones and joints* Lea and Febiger Philadelphia.

Lewis R W (1947) Roentgendiagnosis of pigmented villonodular synovitis and synovial sarcoma of the knee joint *Radiology* 49 26

Lichtenstein L (1955) Tumors of synovial joints bursae and tendon sheaths *Cancer* 8 816

McMaster P E (1960) Pigmented villonodular synovitis with invasion of bone *J Bone Jt Surg* 42 A 1170

Moberger G Nilsonne U & Friberg S Jr (1968) Synovial sarcoma *Acta orthop scand* Suppl 111

Nilsonne U (1966) Pigmenterad villonodulär synovit. *Nord Med* 76 895

Rein B I Bilodeau L P & Johanson P (1964) Arthrography and arteriography in pigmented villonodular synovitis of the knee *Amer J Roentgenol* 92 1322

Smith J H & Pugh D G (1962) Roentgenographic aspects of articular pigmented villonodular synovitis *Amer J Roentgenol* 87 1146

Wright C J E (1951) Benign giant cell synovioma. *Brit J Surg* 38 257

Wright C J E (1952) Malignant synovioma *J path Bact* 64 585

Acta orthop Scandinav 40 461–465 1969

From the Department of Orthopaedic Surgery (Heads J Falkenberg and E. B Olesen) the Central Hospital Naestved Denmark.

ABNORMALITY OF THE ISCHIOPUBIC JUNCTION

Report of a Case

M Blichert Toft & H Kålund Jensen

Received 26 ii 68

The occurrence of radiographic changes in the synchondrosis between the inferior pubic ramus and the inferior ischial ramus in children has been recognized for a long time *Odelberg* (1923) and *van Neck* (1924) were the first to describe changes termed ischiopubic osteo chondritis The radiographic findings in these patients are swelling and demineralization of the ends of the bones adjacent to the syn chondrosis Clinically the changes may be accompanied by pains in the hip the groin or the gluteal region and by limping and restricted movement In a few patients there is in addition tenderness of the synchondrosis and a swelling palpable per rectum

Subsequently attention has been directed towards this clinical syndrome also termed van Neck s ischemic necrosis From a review of the literature about 60 cases were found

In their series relating to the fusion of the ischiopubic synchondro sis in normal children *Heeren* (1933) *Praetje* (1934) *Junge & Heuck* (1953) and *Caffey & Ross* (1956) demonstrated radiographic findings which corresponded completely to the findings described by *Odelberg* and *van Neck* Hence *Caffey & Ross* state that in the age group between 6 and 9 years swelling and demineralization of the ischiopubic syn-chondrosis were found on one or both sides in upwards of 50 per cent The incidence of these findings was higher among girls In the normal series a few cases were found presenting clinical signs similar to those described inter alia by van Neck and most recently *Byers* (1963) and consequently it is doubtful whether it is justifiable to consider ischio-pubic osterochondritis to be an independent entity Several authors among them *Caffey & Ross* and *Byers* suppose that these changes are transitory stages of the normal fusion of the synchondrosis



Figure 1 Radiograph of the pelvis in a 14 year old girl showing ischiopubic osteochondrosis on the left On the right a 22 mm wide gap is noticed between the bone ends of the inferior ischial ramus and the inferior pubic ramus Check radiograph 18 months later shows unchanged conditions

The object of this paper is to report a patient with symptoms resembling osteochondritis but with a radiographic appearance of the ischiopubic synchondrosis which has not been described previously

CASE REPORT

A 14 year old girl (Record No 530624) was admitted to hospital because of pains in the hip Family history non contributory Normal delivery The pregnancy was normal and the mother had not taken any drugs

Because of inguinal hernia of the right and left side, respectively she was operated on at the ages of 18 months and 7 years At the age of ten she was admitted to a cardiological unit for examination because of a suspected congenital heart disease. Ventricular septal defect was diagnosed but no symptoms of cardiac insufficiency were found

The onset of the present symptoms was about 1 month before this admission with pains in the right hip joint and limping No previous trauma or intercurrent diseases The patient was admitted to a local hospital and on the basis of the radiographic findings the case was regarded as a traumatic lysis of the right ischiopubic synchondrosis She was treated by rest in bed in 14 days and was then transferred to the department of Orthopaedic Surgery Naestved

On admission to the latter unit physical examination revealed a slender dark haired well built girl Height 159 cm weight 43 kg No sign of cardiac insufficiency

The secondary sexual characters were well developed (*menstrual function not yet* established)

She walked with a slight limp but without any pain A slight displacement of the pelvis downwards and to the left was found and was accompanied by a shortening of 1 5 cm of the left leg No palpable swelling or tenderness of the ischiopubic synchondrosis was present. Neither by rectal nor external palpation were spasms of the adductor muscles observed, and passive movements of the hips were full.

During her stay in hospital, the patient was given corrective and walking exer cises and a 1 cm higher heel was built on the left shoe She was discharged on the tenth day at which time she walked normally and without pain At the follow up examination in the outpatient clinic 18 months later unchanged conditions were found

Laboratory investigations showed normal values as did renal function tests. Radiographic examination of the pelvis revealed on the left side an ischiopubic osteochondrosis with slight rarefraction prominence and demineralization (Figure 1) The corresponding region on the right showed a gap of ?2 mm. The adjacent bone ends were smooth with normal osseous structure (Figure 1) 18 months later radio graph of the pelvis showed unchanged conditions Radiographs of the knees wrists and shoulders showed normal conditions. Chromosome examination normal (The University Institute of Human Genetics Copenhagen)

DISCUSSION

According to Pratje the ossification of the ischiopubic synchondrosis falls into four stages Stage I comprises cases with an intervening cartilaginous bar not more than 1 mm thick During stages II III and IV fusion of the gap begins and continues Pratje considers stage II as the time of the beginning of the fusion and states the normal age interval for this stage to be between 4 and 5 years for girls limits 3 and 10½ years More recent authors (*Caffey & Ross*) have recorded the time of fusion as being at the age between 4 and 12 years The differ ence between the times of fusion of the ischiopubic synchondrosis re ported in these two series is caused by the fact that the latter authors apply Pratje s stage III and IV On the basis of the above series we find it justifiable to consider our case to be with no ossification of the ischiopubic synchondrosis since a control period during 1½ years does not reveal any change of the defect and the patient now must be con sidered as fully matured

In our opinion the possibility can be discounted that the lesion is a stress fracture or possibly a traumatic lysis of the synchondrosis since 18 months later the radiograph showed no formation of callus just as the clinical picture does not lend support to these assumptions

On review of the literature only one case could be found resembling

our case radiologically (*Janker* 1930) That case was considered to be anomalous ossification of the ischiopubic synchondrosis in a 26-year old woman but subsequent radiographic examination revealed formation of callus corresponding to the defect indicating fracture or possibly lysis of the synchondrosis

No features suggesting endocrine disorders were found in our patient in particular no signs of myxodema On the basis of our examinations we find that the presence of congenital malformations like enchondral dysostosis and cleido cranial dysostosis can be discounted in which cases a delayed fusion of the ischiopubic synchondrosis can be seen

Occasionally delayed unilateral fusion of the ischiopubic synchondrosis can be seen in connexion with shortening of the lower extremities because of disorders such as Perthes disease poliomyelitis hemiplegia and congenital femoral defects (*H J Kaufmann* 1964) None of these disorders could be found in our patient

The asymptomatic osteochondrosis of the left ischiopubic synchondrosis is considered to be part of the normal fusion process

SUMMARY

A case with no ossification of the ischiopubic synchondrosis in a 14 year old girl is described On the basis of previously published normal series relating to the fusion of the ischiopubic synchondrosis the justification of considering the case to be a missing ossification is discussed Diseases which may exert an influence on the fusion of the ischiopubic synchondrosis are mentioned with a view to the differential diagnosis

REFERENCES

Byers P D (1963) Ischio Pubic Osteochondritis *J Bone Jt Surg* 45 B 694 702

Caffey J & Ross S E (1956) The ischiopubic Synchondrosis in Healthy Children Some Normal Roentgenologic Findings Amer Roentgen 76 488–494

Heeren J (1933) Über röntgenologisch nachweisbare Veränderungen der Scham Sitzbein Epiphyse und ihre klinische Bedeutung *Röntgenpraxis* 5 12–16

Janker R. (1930) Fraktur oder Ossifikationsstörung an der Sitzbein Schambein grenze? *Röntgenpraxis* 2 499–501

Junge H & Heuck F (1953) Die osteochondropathia ischiopubica (Gleichzeitig ein Beitrag zur normalen Entwicklung der Scham Sitzbeingrenze im Wachstums alter) *Fortschritte auf dem Gebiete der Röntgenstrahlen* 78 656–668

Kaufmann H J (1964) *Röntgenbefunde am kindlichen Becken bei angeborenen Skelettaffektionen und chromosomalen Aberrationen* P 1–15 Georg Thieme Verlag Stuttgart

Neck, M van (1924) Osteochondrite du pubis *Arch Franco Belges de Chir* 27 238-240

Odelberg A (1923) Some Cases of Destruction in the Ischium of Doubtful Etiology *Acta chir scand* 56 273-284

Pratje A (1934) Über die Ossifikation des Beckens *Anat Anz (Erg H)* 78 53-61

Acta orthop Scandinav 40 466–478 1969

Orthopaedic and Radiological Departments (Chiefs T Jerre and G Sohrne)
Västerås.

STABLE FIXATION IN THE INTERTROCHANTERIC OSTEOTOMY

T JERRE & G TILLING

Received 4 v 68

McMurray (1935) described the intertrochanteric osteotomy as a method of treatment for osteoarthritis of the hip joint and ever since this operation has had a prominent place in this respect. As fixation after the osteotomy McMurray himself used a plaster spica for 4 or 5 months In order to escape the prolonged immobilization in a plaster spica a variety of surgical appliances have later been designed for example by Kessel Bosworth, Wainwright Tupman, McKee Nissen, and others

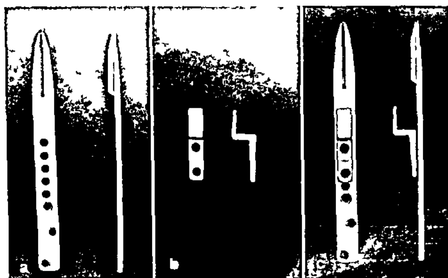
A common feature of them all is however that the appliances have not been able to ensure a stable fixation As a result the number of non unions has as a rule been quite considerable even in the hands of those authors using quite prolonged postoperative bedrest Various authors report the non union rate from 3 to 28 per cent (Table 1)

The poor fixation ability of the usual type of splines results from far too insufficient support medially within the spongious substance

Table 1 Incidence of non union

Authors	Operations	Non union
King & Dooley (1962)	37	3 (8 %)
Ottolenghi & Frigerio (1962)	103	6 (6 %)
Crellin & Simurda (1965)	34	6 (17 %)
Rosborough & Stiles (1967)	108	14 (13 %)
Scott (1967)	100	11–20 (11–20 %)
Green (1967)	225	7 (3 %)
Rosendahl & Ernst (1967)	60	17 (28 %)
Tillberg (1967)	97	6 (6 %)
Lucht & Tarp (1967)	57	5 (9 %)

Figure 1 Intertrochanteric osteotomy fixed with a Kessel spline
Figure 2 \ arus deformity due to unstable fixation with a Kessel spline



Kigure 3 The authors appliance a The spline seen in front and from the side b The hook. c. The hook applied to the spline.

in the proximal fragment, giving rise to varus deformity and instability in the osteotomy (Figures 1 and 2)

In order to ensure a better fixation one of the authors (T Jerre) has together with Elof Törnros, engineer with Stille Werner Stockholm, designed the appliance demonstrated in Figure 3 Initially the appliance was made of stainless steel, nowadays of vitallium

TECHNIQUE

An oblique osteotomy is done in the usual way immediately above the lesser trochanter The distal fragment is displaced medially The spline is hammered up into the proximal fragment, until the tip of the spline has perforated the cortex of the greater trochanter When hammering the spline upwards, one must by counterpressure on the lateral cortex of the proximal fragment, prevent it from tilting into varus and it is also very essential that the spline is placed as far laterally as possible

The hooks are delivered in 6 different sizes as far as the intermediate part is concerned 10–15 mm The biggest one is now placed on the spline so that the two holes in the hook correspond exactly to two holes in the spline Finer adjustment of the spline is now achieved by gently hammering it upwards into the proximal fragment so that the distance between the lower edge of the proximal fragment and the intermediate part of the hook is 3 mm (Figure 4) If this distance is too great the hook has too poor a grip on the proximal fragment If the distance is too small compression in the osteotomy by weight bearing is hindered a compression that is highly desirable for stability and union

It may very occasionally happen for example when the skeleton is very big and/or the osteotomy too oblique that the spline must be hammered so far up into the proximal fragment before the tip perforates the cortex of the greater trochanter that the hook cannot be fixed to the spline in such way that a distance of 3 mm is obtained In this case one quite simply removes either by saw or with chisel enough of the lateral lower edge of the cortex of the proximal fragment that the distance to the intermediate part of the hook is the desirable 3 mm

The osteotomy is now adjusted to get the best possible contact between the osteotomy surfaces with the spline lying close to the cortex of the femur The spline is fastened by 2 or 3 screws to the femur

A correct size hook now must be found Here one always starts with



Figure 4 Skeletal preparation with the appliance

the biggest hook (15 mm) and proceeds to hooks in diminishing order The first hook that cannot by finger pressure be applied close to the spline is chosen as the correct one There is thus to be left a minimal interval between the spline and the hook when the hook is pressed hard with the fingers against the spline The hook is fixed by 2 screws through holes in the spline and should perforate both the lateral and the medial cortex of the femur The screws are tightened so that the above mentioned interval between the hook and the spline disappears and the hook lies close to the spline

With this appliance the osteotomy should be made quite oblique the authors aim is an angle of about 120 (Figure 4) This is because in this oblique osteotomy the weight bearing forces will produce a tendency for the lower fragment to displace along the osteotomy line upwards and medially but this is effectively prevented by the hook If the osteotomy is too horizontal the weight bearing forces will tend to produce varus tilting in the osteotomy which the hook cannot effectively prevent If the tilting is pronounced one risks that the hook loses its grip on the lateral cortex of the proximal fragment altogether





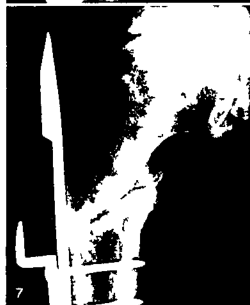


Figure 5 Typical case 3 days post operatively

Figure 6 Typical case 4 months post operatively

Figure 7 Typical case 9 months post operatively

Two days after the operation the patient is allowed to sit up in a chair After one more day the patient is encouraged to start walking with 50 per cent weight bearing on the operated leg with support of two elbow crutches and continues in this manner until radiological evidence of union is satisfactory The patients have as a rule been kept in the hospital for 2–4 weeks after operation for walking exercises

Since April 1966 61 hips have been operated by the method de

scribed above In this material there are only cases of advanced osteoarthritis of the hip joint and no operations on early cases as suggested by Nissen (1963) have been done In the beginning of April 1968 34 patients had a follow up period of at least 6 months (Table 2) The age distribution is shown in Table 3

Table 2 Sex-distribution and frequency of right left and bilateral cases

	Right	Left	Bilateral	No of patients	No of hips
♂	9	6	3	18	21
♀	8	8	0	16	16
Total	17	14	3	34	37

Table 3 Age distribution

< 40	40–49	50–59	60–69	> 70
2	2	8	20	2

Complications Two patients died both 11 days after operation one of uraemia the other of massive pulmonary embolism In both cases the osteotomy was unchanged and quite stable

In one case (No 14) the spline bent at the level of the osteotomy resulting in varus tilting in the osteotomy (Figure 8) This spline belonged to an earlier series of thinner splines made of stainless steel The tilting occurred during a period of walking exercises in a very obese patient between the fourth and the fourteenth postoperative days A progressing adduction contracture developed and 2 months after operation this was about 20 with functional leg shortening of about 10 cm Reoperation was performed a new spline introduced in the canal of the old spline This spline has not been stably fixed in the old canal and continued X ray controls have demonstrated absorptions around the spline in the proximal fragment showing that it is loose The union of the osteotomy has therefore not progressed normally and the osteotomy line has not yet at 13 months after re-operation been obliterated The unsatisfactory result in this case has its full explanation in the fact that the first spline bent and the new spline

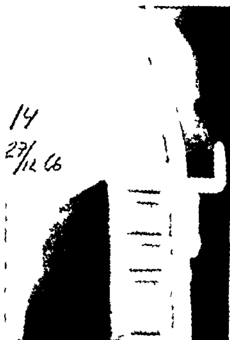


Figure 8 Case No 14 The spline has bent

was not stably fixated in the old canal This was the only case in the entire series in which a spline bent and in this case a stainless steel spline of a thinner type had been used This complication should surely not be feared now with the use of vitallium splines which are double the strength of the stainless steel ones

In one case (No 15) the fixation of the osteotomy became unstable resulting in varus tilting, because of wrong surgical technique The osteotomy has been made almost horizontal (Figure 9) The spline should have been hammered further up into the proximal fragment so that the distance between the lower femoral cortex of the proximal fragment and the intermediate part of the hook was only 3 mm and not as in this case 11 mm On the original X rays one can see a small space between the hook and the femoral cortex proving that in this case a hook with too large an intermediate part has been selected These three errors combined made the appliance unable to prevent the varus tilting so often observed with previously used osteotomy splines (Figure 10) Because of the unstable fixation, the union in this case has not progressed normally and the osteotomy line is still 13 months after the operation not completely obliterated Signs of non union are however not present and sound union is expected to take place gradually

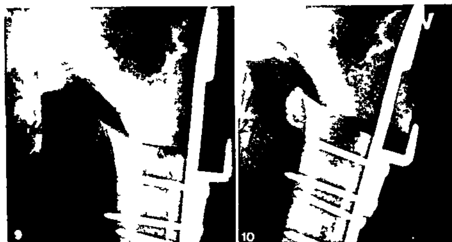


Figure 9 Case No 15 The osteotomy too horizontal Too large an interval between the lower edge of the proximal fragment and the intermediate part of the hook The intermediate part of the hook is too big

Figure 10 Case No 15 Because of the faults mentioned the fixation has been unstable and varus deformity has developed

Only in one case did a slight superficial wound infection occur this disappeared quickly without consequences

Postoperative thrombosis in the operated leg occurred in 8 cases

Of the 34 patients with at least a 6-months follow up period 2 have died The remaining 32 have been examined in the months of February–April 1968 clinically and radiologically all by the authors personally Three of these cases are bilateral and the number of operated hip joints on follow up examination is therefore 35

The presence of pain at rest and on weight bearing before and after operation is shown in Table 4 Complete freedom of symptoms regarding pain at rest has been obtained in 89 per cent and in 80 per cent for pain on weight bearing and an improvement which the patients have in all cases reported as important in 11 respectively 20 per cent Within the short time of observation in this small material a 100 per cent improvement has been obtained for both pain at rest and pain on weight bearing a very good result indeed compared with previous authors Adam & Spence (1958) report an improvement of pain in 81 per cent Robins & Piggot (1960) in 92 per cent Hirsch (1961) in about 80 per cent Nicoll & Holden (1961) in 88 per cent Ottolenghi &

Table 4 Pain at rest and on weight bearing

		Pain at rest	Pain on weight bearing
Preoperatively		33 (94 %)	34 (97 %)
At follow up	None	31 (89 %)	28 (80 %)
	Decreased	4 (11 %)	7 (20 %)
	Unchanged	0	0
	Increased	0	0

Table 5 Pre and postoperative mobility

	Extension – flexion	Abduction – adduction	Internal rotation – external rotation
Increased	13 (37 %)	9 (26 %)	9 (26 %)
Unchanged	21 (60 %)	26 (74 %)	23 (66 %)
Decreased	1 (3 %)	0	3 (8 %)
Average preoperative mobility	84	21	13
Average postoperative mobility	97	30	19

Frigerio (1962) in 94 per cent Howe et al (1963) in 97 per cent and Lucht & Tarp (1967) in 95 per cent

The range of movement before and after operation is shown in Table 5 Our investigation shows in accordance with the majority of previous authors (Nicoll & Holden 1961 King & Dooley 1962 Ottolenghi & Frigerio 1962 Bucht & Tarp 1967 and others), in some cases improvement in some cases no change and in other cases deterioration as regards range of movements in various planes

At follow up 15 patients walk without limp Ten patients have slight limp and 4 a moderate one Four quite newly operated patients all with only 6 months period of observation still walk with the support of 2 elbow crutches on our instructions Permanent limp cannot as yet be judged for these 4 cases nor case No 14 or No 15 (see above) who also still use one or two elbow crutches in accordance with our instructions

Fourteen patients do not use a stick 12 patients use one stick for

outdoor use 3 patients use one stick both outdoors and indoors and 6 patients (see above) one or two elbow crutches on our instructions

Seventeen patients have no measurable leg shortening In 18 cases a leg shortening has been registered on the operated leg which in 11 cases amounts to 1 cm in 3 cases to 1 5 cm and in 4 cases to 2 cm

Of the 28 patients who at operation were under 67 years old 17 have returned to their previous work (2 farmworkers 7 factory workers one butcher one manageress of a nursery and 6 housewives)

Of those who have not yet returned to their previous work is one bilateral case (farmer) followed up for 17 respectively 7 months cases Nos 14 and 15 (see above) and 7 patients followed up for only 6 months

Preoperatively all the cases have presented radiological signs of osteoarthritis in the hip joint these have of course been of varying degree but in all cases these osteoarthritic changes have been ad vanced and in some cases very advanced

Callus has been radiologically observed within 2 months after opera tion in 15 cases between 2–3 months postoperatively in 16 cases and between 3–4 months in 4 cases

In the authors opinion it is impossible to decide the earliest time when an osteotomy can be regarded as united Not until the osteotomy line is completely obliterated has one an absolutely safe proof of union

In the material now presented a complete obliteration of the osteo tomy line has been observed radiologically within 6 months in 12 cases within 9 months in another 12 cases and within 12 months in yet another 3 cases In 4 cases the osteotomy line can still be observed 6 months after operation in one case 10 months after operation and in one 13 months after operation None of these cases presents any signs of non union whatsoever all show progressing union In case No 14 and case No 15 the osteotomy lines are not yet obliterated 13 and 15 months respectively after the operation

It is very often seen on X rays that the joint space increases after an intertrochanteric osteotomy Previously many authors explained this as a shift of the position in the acetabulum of the head after the osteotomy Almost all agree now that this is the correct explanation for some cases but that there is in addition often a real improvement of the osteoarthritic changes in the hip joint that is shown by from time to time increasing joint space decreasing size of the cysts typical for osteoarthritis and/or decreasing amount of subchondral sclerosis



Figure 11 a Preoperative X ray b X ray 17 months postoperatively shows a considerably increased joint space and regression of both cysts and subchondral sclerosis

In 15 cases in this material it has been possible to demonstrate a continuing increase in joint space, which in 9 cases has been accompanied by decreasing of the cysts and of subchondral sclerosis In 3 cases without increase in joint space disappearance of osteoarthritis cysts has been seen which has been so marked that we have judged this as a safe sign of improvement of the osteoarthritis in the hip joint Radiologically we have therefore in 18 cases altogether found regression of the osteoarthritis changes In the short time of observation we have not found deterioration of the osteoarthritis changes in any case

CONCLUSIONS

The results obtained by the authors with this vitallium surgical appliance in cases of osteoarthritis of the hip joint must be regarded as very good in comparison to previously published series

It is the authors opinion that because of the stable fixation given by the presented appliance the following has been gained

1 The postoperative recumbency can be shortened very considerably
2 Because of the shortened recumbency primary complications above all deep vein thrombosis and embolism should be expected to decrease in number

3 Time in hospital can be shortened very considerably
4 The very frequent non unions in previous publications might with this appliance and with correct surgical technique be completely *eliminated and the final results improved in comparison* with those obtained with previous appliances

Since the authors designed and started to use the above described appliance Wainwright Hammond Osborne Ball Harris and the AO group in Switzerland have reported other appliances for providing stable fixation and compression of the osteotomy The compression gained with these appliances which quite correctly great importance is attached to can without doubt be gained as effectively and further continuously through weight bearing with our appliance

The appliance is available from AB Stille Werner Stockholm

SUMMARY

The authors describe a new fixation appliance for intertrochanteric osteotomy This appliance gives a stable fixation with compression through weight bearing It has been used with good results in 61 intertrochanteric osteotomies and 37 cases with an observation period of at least 6 months are reported here

REFERENCES

Adam A & Spence A J (1958) Intertrochhanteric osteotomy for osteoarthritis of the hip *J Bone Jt Surg* 40 B 219–226

Crellin R Q & Simurda M A (1965) Intertrochanteric osteotomy of the femur for osteo arthritis of the hip *Brit J Surg* 52 437–439

Green J P (1967) Union of intertrochanteric osteotomies *J Bone Jt Surg* 49 B 488–494

Hirch C (1961) Intertrochanteric osteotomies in osteoarthritis of the hip *Acta orthop scand* 30 129–136

Howe W W, Humma G T & Duthie, R (1963) Treatment of the painful hip with displacement intertrochanteric osteotomy *J Bone Jt Surg* 45 A 1328–1329

King T & Doolcy B (1962) *Observations on the late results of the McMurray* osteotomy for osteoarthritis of the hip *J Bone Jt Surg* 44 B 595–601

Lucht U & Tarp M (1967) Osteoarthritis of the hip treated with intertrochanteric displacement osteotomy *Acta orthop scand* 38 501–519

McMurray T P (1935) Osteoarthritis of the hip-joint *Brit J Surg* 22 716–727

Nicoll E A & Holden N T (1961) Displacement osteotomy in the treatment of osteoarthritis of the hip *J Bone Jt Surg* 43 B 0– 60

Nissen K I (1963) The arrest of early primary osteoarthritis of the hip by osteotomy *Proc. roy Soc Med* 56 1051 1060

Ottolenghi C E & Frigerio E (1962) Intertrochanteric osteotomies in osteoarthritis of the hip *J Bone Jt Surg* 44 A 855-895

Robins R H C & Piggot J (1960) McMurray osteotomy *J Bone Jt Surg* 42 B 480-488

Rosborough D & Stiles P J (1965) The problem of union following intertrochanteric osteotomy with internal fixation for osteoarthritis of the hip *J Bone Jt Surg* 48 B 178

Rosborough D & Stiles P J (1967) Non union after intertrochanteric osteotomy with internal fixation for osteoarthritis of the hip *J Bone Jt Surg* 49 B 462-474

Rosendahl S & Ernst J (1967) The results of osteotomy and osteosynthesis in coxarthrosis *Acta orthop scand* 38 387

Scott, P J (1967) Non union of oblique displacement intertrochanteric osteotomy for osteoarthritis of the hip *J Bone Jt Surg* 49 B 475-487

Tillberg B ((1967) Results of intertrochanteric valgus osteotomies in hip arthrosis. *Acta orthop scand* 38, 387

Acta orthop Scandinav 40 479–500 1969

Departments of Orthopaedic Surgery (Head C. Hirsch, M D) and Roentgenology I (Head O Bartley M.D) University of Goteborg Sweden.

A CLINICAL AND RADIOLOGICAL FOLLOW UP STUDY OF TRANSIENT SYNOVITIS OF THE HIP

ALF NACHEMSON & SVEN SCHELLER

Received 11 v 68

Transient synovitis of the hip (coxitis simplex irritable hip observation hip) is well known in the literature and many papers have been published concerning the diagnosis and clinical features of the disease (among others by Rauch 1940 Colonna 1941 Lucas 1948) There have been discussions about its conceivable importance for later occurrence of osteoarthritis in the affected hip (Harrison Schajowicz & Trueta 1953 Murray 1965)

Few long term follow up studies have been published In 1963 Valderrama reported from a material of 189 children 23 cases followed for at least 15 years with clinical and radiological examinations Holenstein (1966) followed 12 out of 37 cases for periods between 5 and 27 years and Spock (1959) and Adams (1963) have reported series of about 50 cases each followed for an average of 5 years

Valderrama (1963) regarded the disease as rather serious since about 50 per cent of 23 cases followed by him showed radiological and clinical symptoms of hip disease probably related to the previous transient synovitis He also mentioned that there were more radiological signs than clinical and that adequate investigations into normal hip radiograms in patients 20–30 years old are lacking in the literature Holenstein (1966) questioned the benignity of the disease on the basis of 12 cases out of whom 2 had subjective complaints 7

The authors are indebted to Dr K. G Herrlin Vejbystrand for the use of the patients data in the initial stages of the diseases, which he collected in 1949–1952, while working at the Hospital for Sick Children in G teborg.

This study was supported by grants from Forsta Majblommans Riksforbund and Ulla och Gustaf af Ugglas fond.

slight limitions of hip mobility and 5 some radiological changes like broadening of the femoral head and neck and calcifications

It is known that a few patients with transient synovitis of the hip after some time will develop Perthes disease (coxa plana) According to Spock (1959) this will occur in 6 per cent of the cases

In this study based on a material of 73 cases of transient synovitis of the hip followed for 20-22 years the clinical and radiological development of the disease has been investigated A separate roentgenographic study of 36 subjects of comparable ages without any previously known hip disease has been included first to study normal standards in this age group and second to serve as a basis for comparison

MATERIAL AND METHODS

Clinical Evaluation

The material consisted of 102 patients treated at the Hospital for Sick Children in Goteborg during the years 1945 1946 and 1947 All the children fulfilled the criteria mentioned among others by Spock (1959) for the diagnosis of transient synovitis e g subacutely occurring pain in one hip with painful limitation of motion slightly elevated temperature moderate increase of sedimentation rate negative radiogram of the hip and a relatively quick and uncomplicated recovery

Out of the total 102 patients 6 later developed Perthes disease in the affected hip and were excluded (Table 1)

Table 1 Material

Diseased in year	Prelim diagnosis trans synov	Defin diagnosis trans synov	Defin diagnosis coxa plana	Follow up (20-22 years) Clinical and radiol exam	Contacted by questionnaire
1945	27	24	3	20	0
1946	38	36	2	23	5
1947	37	36	1	24	1
	102	96	6	67	6
				(76%)	

It was possible to trace 73 of the remaining 96 patients Of these 67 were personally evaluated at a follow up which was performed at the end of 1967 and in the beginning of 1968 Six additional patients responded to a questionnaire. Thus 76 per cent of the original material was followed for 20-22 years. A summary is given in Table 2 of pertinent data at the time of onset of the disease for these 73 patients

The remaining 23 patients were lost for follow up A statistical analysis of the preliminary findings in the 73 patients followed compared with those of the 23 that could not be traced demonstrated no difference with regard to sex age, sedimentation rate temperature rise on admission or treatment. From a statistical point of view it is thus likely that the results obtained in the followed group are representative The clinical examination included an interview in which the subjects were specifically asked for recurrences and previous or present allergic tuberculous or rheumatic diseases Any subjective complaints from the hip joints were noted. The orthopaedic evaluation included control of gait measuring of joint motion and leg length The different motions recorded were extension (lying on one side with the lower hip maximally flexed) flexion (supine, the other leg extended) adduction (supine) abduction (supine) rotation (supine with hip in 90 of flexion as well as in extension)

The leg length was measured by recording with measuring tape, the distance from the anterior superior iliac spine to the tip of the medial malleolus.

At the examination great care was taken to compare the two hips In all except three cases neither the examiner nor the patient knew until after the examination which of the two hips had been previously diseased.

Radiographic Evaluation

Of the 73 patients followed radiograms were obtained from 67 Of these 58 had also been roentgenographically examined within one week after the initial admission to the hospital.

The control group contained 36 persons e.g 72 hip joints who gave no history whatsoever of hip joint disease In this group there were 19 males and 17 females with the medium age of 25 years (20–34 years)

The roentgenographic examination which was performed in the same manner at the time of hospitalization and at follow up included an antero posterior view of the pelvis and separate films of each hip joint in both the frontal and the Lauenstein projections The roentgenographic examination aimed only at obtaining an appraisement of the skeleton and not of the soft tissues.

At follow up the films from the two hip joints in each patient were compared especially with regard to the width of the joint space and the form and magnitude of the femoral head. The presence was registered of osteophytes or other irregularities on the edge of the joint surface of the femoral head as well as irregularities of the spongiosa in the form of cysts or islands of compact bone. Such findings were also noted in the femoral neck and in the acetabulum. Around the acetabulum, calcifications as well as ossifications like os acetabuli near the joint space were registered. The examiner did not know which of the patient s two hips had previously been diseased

RESULTS OF THE CLINICAL FOLLOW UP

History

Of the 73 interviewed patients 12 gave a history of some type of pain or discomfort from one of the hip joints (Table 3) In none of these

Table 2. Summary of initial clinical findings in 73 patients

Sex		Age (yrs)		Sediment. rate (mm)	
Males	Females	mean	range	mean	range
48	25	7.1	1–13	11.6	2–35

were the symptoms of such magnitude that the patients had sought medical advice except in one case. This patient was a woman of 35 years who had been hospitalized for 105 days 22 years previously because of persisting symptoms of hip synovitis. The radiograms had been negative on admission as well as dismissal from the hospital in 1945. Two years later she was re-admitted under the same diagnosis for 10 days. At that time a coxa magna was seen. There had been no signs of other diseases on these two occasions, nor was there any evidence of such at the follow-up. Of the 12 patients with subjective complaints 9 had had their transient synovitis on the same side, whereas 3 complained of slight troubles from the previously unaffected side (Tables 3 and 9).

Table 3. Subjective complaints 12/73 patients (16.4%)

	Originally diseased hip	Positive radiogram (only 67 pat. examined)	Lim. of motion (>10°) (only 67 pat. examined)	Originally unaffected hip	"Positive radiogram (only 67 pat. examined)	Lim. of motion (>10°) (only 67 pat. examined)
Some starting stiffness or discomfort	4	3	1	0		
Occasional pain walking long distances	4	4	3	3	3	2
Pain when walking sometimes at rest	1	1	1	0		
	9 (12.3%)			3 (4.1%)		

Altogether 12 of the 73 patients (16.4 per cent) gave some history of an allergic disposition. Three had had asthmatic troubles in childhood and the remaining 9 had reacted to flowers or food severely enough to be medically treated.

h transient synovitis of the hip followed 20–22 years

mp on admission (C)		Hospitalization (days)		Treatment		Radiograms obtained
ean	range	mean	range	Bedrest	Traction	(all neg)
37 5	37 0–40 2	13 2	1–105	11	62	62

Clinical Examination

Altogether 18 of the personally evaluated 67 patients had some limitation of motion of either hip joint (Differences less than 10 have been excluded) These limitations never exceeded 20 The motion qualities most often restricted were inward rotation (10 patients) flexion (6 patients) and extension (5 patients)

15 patients exhibited some limitation on the affected side 3 on the other side Reduced motion in more than one of the tested directions occurred in 6 cases only all of whom had had their transient synovitis on the same side Statistically there is a definite correlation between previous transient synovitis and limitation of motion

Of those 12 patients with subjective symptoms from one hip 7 also had limitation of motion on the same side (Table 3) and one was limited in extension on the other side The correlation between discomfort or pain from the hip and limitation of motion in the present material is not significant

29 had leg length differences of 1 or 2 cm 17 were shorter on the originally affected side and 12 were longer

Two patients had recurrence of their transient synovitis 2 and 3 years respectively after original onset One was the female patient with more pronounced complaints mentioned above the other one also a female at follow up had no subjective complaints and showed a limitation of extension of 10 but had no radiographic changes

RESULTS OF THE RADIOLOGICAL FOLLOW UP

As previously mentioned the original radiograms revealed no pathologic changes in the hip joints of the 62 patients examined on admission to the hospital 20–22 years earlier These radiograms have been re considered for the present study without any change of the initial appraisal At follow up negative radiograms were found from both hip joints in 21 of the 67 patients A positive radiogram of some

kind was seen in 46 patients of which 23 had changes in one hip joint and 23 had bilateral changes Thus a positive radiogram was found in 69 and a negative in 65 hip joints From Table 4 the presence of a positive or negative radiogram in the two hip joints can be seen In the previously diseased hip a positive radiogram was found in 40 and a negative in 27 cases In the previously non affected hip 29 exhibited positive findings and 38 were normal

Table 4 The incidence of roentgenographically positive and negative joints in the previously diseased and unaffected sides of 67 patients at follow up

	Roentgenographic findings		Total
	+	—	
Previously diseased hip	40	27	67
Previously unaffected hip	29	38	67
Total	69	65	134

As mentioned above the positive findings at radiography were located in (1) *the joint space*, (2) *the head of the femur*, (3) *the neck of the femur*, and (4) *the acetabulum*

1 *Joint Space* (Table 5)

A decreased height of the joint space was seen in one of the hips in 4 patients In 2 of these the whole joint space was 1–2 mm lower than in the other hip and in another 2 patients this reduced height was seen only in the medial part of the joint

Table 5 Incidence of radiographic changes in the femora[l]

	Joint space				*Femora[l]*
	Narrow	*subj compl*	*lim of motion*	*Caput magnum*	*subj compl*
Previously diseased hip	3	2	1	7	1
Previously unaffected hip	1	0	0	3	1
No of joints	4			10	
Bilateral	0			–	

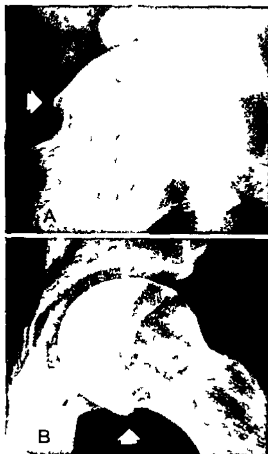


Figure 1 Osteophytes on the edge of the femoral head
A Laterally situated in the previously diseased hip of a 27 year old male
B Posteriorly situated in the previously unaffected hip of a 26 year old female

:ad and joint space narrowing in 67 patients at follow up

:ad						
lim. of motion	*Osteo phytes*	subj compl.	lim of motion	*Dense spots*	subj compl.	lim of motion
1	9	1	2	3	1	1
1	9	3	2	2	0	0
	18					
	5			0		

Figure 2 Cysts in the femoral neck A Multiple rounded cyst laterally in the previously diseased hip of a 29 year old male B Solitary triangular shaped cyst laterally in the previously diseased hip of a 28 year old male



Three of these 4 hip joints had previously been affected by transient synovitis whereas the fourth was previously unaffected In this patient the whole joint space was narrower than in the other previously diseased hip

2 *Head of the Femur* (Table 5)

(a) *Caput magnum* In 10 patients the femoral head on one side was bigger than on the other side The comparison was made by measuring the transverse diameters in the A P view A difference was only recorded if it exceeded 1 mm In none of the cases was the difference more than 3 mm

Seven of these 10 hip joints with a larger head had previously been diseased whereas the other 3 were on the unaffected side



Figure 3 Dense spots in the right hip (A) and the left (B) previously diseased hip of a 2[illegible] year old male

(b) *Osteophytes* (Figure 1) Osteophytes or [illegible] deformities were seen on the edge on the femoral head in 13 patients. Five of these had changes of this type symmetrically located in both the hip joints. [illegible] the 8 remaining cases the osteophytes were located in the [illegible] diseased side in 4 instances.

Altogether 18 hip joints showed osteophytes of which [illegible] viously been diseased. The osteophytic changes were localized on the posterior [illegible] of the femoral head.

The shape and [illegible] the [illegible] rounded [illegible] surface of [illegible]



Figure 5 Os acetabuli *A* In the previously unaffected hip of a 27 year old male *B* In the previously diseased hip of a 22 year old male

Table 8 Radiographic changes recorded at follow up in the diseased and unaffected hips ... history of hip

	No hips X rayed	No negative radiograms	*Joint space* Narrowing	Femoral head Caput magnum	Osteo phytes	Cysts	Dense spots
Previously diseased hip	67	27	3	7	9	0	3
Previously unaffected hip	67	38	1	3	9	0	2
Controls	72	45	1	0	11	1	1

(c) *Calcifications* (Figure 4) These could be seen at the proximal part of the edge of the acetabulum in 17 patients In 4 they were bilateral in 13 unilateral

Altogether 21 hip joints of which 15 previously had been diseased exhibited calcification

They were in all instances located 1–3 mm lateral to the proximal part of the posterior acetabular joint edge They were all round or oval sizes varying from 1 × 1 mm to 3 × 5 mm More than half of them had a diameter exceeding 2 mm In 11 of the 21 joints with this change they were solitary in 8 there were two or three In one patient there were bilateral multiple calcifications

(d) *Os acetabuli* (Figure 5) A true accessory bone with cortical as well as spongious parts located in a small excavation in the proximal part of the posterior acetabular joint edge was seen in two patients one of which had this bone in the previously diseased hip One was oval with diameters 10 × 20 mm the other round 4 × 4 mm

Controls (Table 8)

With the exception of caput magnum all the radiographical changes described in the patients could also be seen in the control subjects One of these also exhibited cysts in the spongiosa of the femoral head a change that was not seen among the patients

Table 8 shows the type and occurrence of the different positive radiographic findings in both the controls and the material of followed patients

... 67 patients with previous transient synovitis of one hip and in 36 controls with no ... ailment

Femoral neck		Acetabulum				Total no radiolog changes
Cysts	Dense spots	Cysts	Dense spots	Calcific	Os acetabuli	
16	8	0	0	15	1	6? in 40 hips
6	5	0	2	6	1	35 in 29 hips
5	1	0	2	12	2	36 in 27 hips

1 *Joint Space*

A narrow joint space was seen in one of the hips in this group

2 *Femoral Head*

(a) *Caput magnum* In this group the size of the two femoral heads equalled each other in all subjects

(b) *Osteophytes* This change was seen in 8 subjects 3 of which had bilateral osteophytes and 5 unilateral, totalling 11 hips with this type of change

(c) *Cysts* This change was seen in the femoral head of one hip in this group, where there were 2 rounded areas of less dense bone each 4 × 5 mm

(d) *Dense spots* One such spot of the size 3 × 5 mm was seen in one femoral head

3 *Femoral Neck*

(a) *Cysts* This change was noticed in one of the hips in five subjects The sizes were the same as seen in the followed material Three located lateral and two medial in the femoral neck

(b) *Dense spots* This change of the size 4 × 4 mm was seen in the lateral part of one femoral neck

4 *The Acetabulum*

(a) *Cysts* As among the patients no cyst localized in the spongiosa of the acetabulum was seen in the controls

(b) *Dense spots* Bilaterally this was seen in one of the subjects in the control group They were rounded 3–5 mm in size and were double in one of the hips single in the other

(c) *Calcifications* With the same localization as among the followed subjects these were seen in 12 hips of the controls In 4 subjects they were bilateral in 4 unilateral In 9 of the hips there was only one calcification in 3 there were two

(d) *Os acetabuli* One of the hips in two subjects exhibited this accessory bone The sizes were 4 × 6 mm and 10 × 14 mm respectively

DISCUSSION

As mentioned in the introduction previously published long term follow up studies on transient synovitis of the hip (Valderrama 1963 Holenstein 1966) have questioned the benignity of the disease These conclusions have been based however on limited series of patients representing only a fraction of the original number of patients

The present study of 73 patients of which 67 were personally examined and radiographed represents 76 per cent of the original material treated at the Hospital for Sick Children in Goteborg during the years 1945–1947 Statistically there was no difference in age sex or the initial stages of the disease between those 23 that could not be traced and the followed 73 patients Thus the conclusion drawn from the present material should be representative

It is well known that some of the patients with coxa plana at the onset of their disease show a similar clinical picture as those with a transient synovitis The development of the condition will disclose the true diagnosis In the present material 6 patients who originally were diagnosed as transient synovitis later (1 month–14 months) developed a coxa plana The incidence is exactly the same 6 per cent as reported by Spock (1959) The aetiology of transient synovitis is not known There have been discussions in the literature about trauma infection rheumatic disease and allergic origin (Spock 1959 Hermel & Albert 1962 Emr 1966) In two different materials (Spock 1959 Hermel & Albert 1962) the incidence of children showing allergic reaction has been 15 per cent and 25 per cent respectively

Spock concluded this to be about the same as in the average general population a view which is supported by the present study where 16 4 per cent gave some history of an allergic disposition

The incidence of allergic manifestations in the adult Swedish population is 13 per cent according to Colldahl (1959 1968) and Kraepelin (1954) reported a 1 4 per cent incidence of asthma in Swedish school children Compared to these figures no statistical evidence of a special allergic disposition in children with transient synovitis can be demonstrated None of the followed cases gave any history of rheumatic or tuberculous disease

In the present material the clinical sequelae of a previous transient synovitis of the hip are relatively mild and far from common In only one patient can it be said that the residual symptoms were of such magnitude that they could be regarded as important This then 13



Figure 6 *Antero posterior pelvic view of a 35 year old female who at follow up reported pain at rest from the previously diseased right hip She also exhibited restricted motion in most directions as well as a noticeable limp The radiogram showed a caput magnum on the right side as well as a cyst in the femoral neck and an osteophyte on the edge of the femoral head (seen in the lateral projections)*

year old girl had persisting symptoms for such a long time that bed rest and traction were maintained for 105 days This prolonged course of the disease might raise the question whether she really had had transient synovitis since one of the criteria mentioned by Spock (1959) was the relatively fast self limiting course On the other hand it was impossible at the time of original treatment at recurrence two years later or at follow up to obtain any other diagnosis (sedimentation rate 7 mm temperature 37 8 on admission and then normal laboratory tests normal cerebrospinal fluid normal) It is also of interest to note that this girl was the oldest in this material Valderrama (1963) mentioned that the older the patients the less benign the disease and the more frequent the development of coxa magna At follow up this patient reported pain when walking exhibited a slight limp was limited in motion in 5 directions and on the radiograms her previously diseased hip showed a caput magnum osteophytes and a cyst in the femoral neck (Figure 6)

With the exception of this case no correlation was found in the present material between on the one hand age or sex of the patient and the preliminary course of the disease (sedimentation rate temperature increase days of hospitalization) and on the other hand the later occurrence of pain or discomfort limitation of motion development of caput magnum or other radiological "abnormalities in the originally affected hip Altogether 12 (16 4 per cent) of the 73 patients reported some pain or discomfort from one of the hips of which 9

(12 3 per cent) located their troubles to the previously diseased hip From a clinical point of view the complaints were mild and only the patient described above had sought medical advice

It cannot be excluded however that these symptoms were very early signs of osteoarthritis (Danielsson 1964) although the roentgeno graphic examination gave little support to this (Tables 3 and 8)

Table 9 Correlation between subjective complaints observed radiographic changes and limitation of motion

			Femoral head				Femoral neck	Acetabulum			
		Patient no	Narrow joint space	Caput magnum	Osteo phytes	Dense spots	Cysts	Dense spots	Calcifi	No observed changes at X ray	Motion restricted (no directions)
Some starting stiffness and discomfort	all prev diseased	1							+	1	0
		2								0	0
		3							+	1	0
		4				+				1	1
Occasional pain walking	prev diseased hip	1	+				+			2	0
		2							+	1	1
		3	+							1	1
		4							+	1	3
	prev unaffected	1			+					1	0
		2			+					1	1
		3						+		1	1
Pain some times also at rest	hip prev diseased hip	1		+	+		+			3	5

Restriction of motion occurred in 18 of the 67 patients examined Of these 15 (22 4 per cent) were restricted in the previously diseased hip As seen from Table 9 only two patients of those with subjective com plaints exhibited limitations in more than 1 direction This also oc curred in another 4 patients without subjective symptoms but in none except the previously mentioned girl was this of clinical significance This patient was also the only one showing a slight limp The localiza tion of the restricted motion to the previously diseased hip was sta tistically significant

According to Danielsson (1964) the diagnosis of osteoarthritis of the hip must be based on radiographic structural or joint space changes, whereas osteophytes appear to be part of the normal ageing in the hip joint The structural changes in the form of dense spots and cysts found in the present material are not identical with those seen in osteoarthritis In this condition irregular areas of hyperdensity are seen between sharply delineated cysts of varying sizes located mainly near the joint surface

The dense spots seen in our material are rounded and sharply delineated, and correspond in form and size to those not uncommonly seen in the epiphysis of long tubular bones Patho anatomically they contain compact spongious bone (Schmorl 1931) The cysts registered in this material are smaller not as sharply delineated and more centrally located than those seen in coxarthrosis

Joint space narrowing was seen in the previously diseased hip in three subjects This incidence is not significantly increased compared with the controls (Table 8)

According to Schmid & Halden (1949) the epiphyses in the two hip joints show a symmetrical evolution An acceleration of growth of the femoral head may occur as a response to a non specific irritation of the growing hip joint This might result in caput magnum

Ferguson & Howorth (1934) and Murray (1947) have among others described this feature following synovitis of the hip joint In our material the incidence of caput magnum in the previously diseased hip was significantly higher than in the controls (7 versus 0 $p < 0.05$)

Since the true cause of transient synovitis of the hip is unknown it is from a statistical point of view not permissible to compare the

Table 10 Frequency of different radiological changes at follow up in the previously diseased and the unaffected hip in 67 patients and in 36 subjects with no history of hip joint disease (controls)

	Patients		Controls
	Prev diseased hip (67)	Prev unaffected hip (67)	(72)
No change observed	27	38	45
1 type of change	26	24	19
2 different types of change	6	4	7
3 different types of change	8	1	1

radiographic findings in the previously diseased and previously unaffected hip in the same patient

Such a comparison can however be made with the 72 hip joints in the control subjects who had no history whatsoever of hip joint disease

As seen from Tables 8 and 10 the number of radiographically negative previously diseased hips were 27 out of 67 in the previously unaffected hips 38 out of 67 and in the controls 45 out of 72 The incidence of different changes registered in the patients and the controls is seen in Table 8 A statistical analysis comparing the incidence of each specific change in the previously diseased hips with that in the controls and the previously unaffected hips with the controls showed a statistically significant higher frequency of caput magnum in the previously diseased hip

The structural changes seen in the femoral neck in the forms of cysts and dense spots are also significantly more frequent in the previously diseased hip than in the controls ($p < 0.05$) The dense spots and cysts reported here differ from those seen in osteoarthritis

The other changes concomitant with osteoarthritis e g joint space narrowing and osteophytes are not seen in an increased frequency in the present material as compared to the controls Thus from a strict roentgenographic point of view the present study has not supported the suggestions of Ferguson & Howorth (1934) Harrison Schajowicz & Trueta (1953) Valderrama (1963) and Holenstein (1966) that a previous transient synovitis might predispose to early osteoarthritis of the hip

On the other hand a caput magnum which could be regarded as a change of epiphysial growth was seen significantly more frequently in the previously affected hip than in the controls No instance of broadening of the femoral neck as reported by Holenstein (1966) was seen in this material

The reason for the significantly increased frequency of femoral neck cysts and dense spots in the previously affected hips is uncertain but there is no evidence that they are of any clinical importance (Table 9)

There were no statistically significant differences with respect to the radiographically recorded changes between the previously unaffected hips and the controls

When the number of hips with one or more radiographically registered changes is tabulated in the different groups as in Table 10 it is seen that those hips with more than two different radiological changes

were significantly more frequent in the previously diseased hip than in the controls The previously unaffected side did not differ from the controls

Thus, the present investigation has demonstrated that the clinical and radiological sequelae of a previous transient synovitis are few and relatively mild

SUMMARY

Of 102 patients with transient synovitis of the hip treated in 1945 1946 and 1947 in the Hospital for Sick Children Goteborg 67 have been subjected to a clinical and roentgenological follow up 6 additional patients were traced and responded to a questionnaire another 6 patients had developed coxa plana (Perthes disease) and were excluded Thus altogether 76 per cent of those with transient synovitis were followed 20–22 years Statistically the conclusions drawn from the present material should be representative

The 6 per cent incidence of coxa plana in patients with the previous diagnosis of transient synovitis agrees with figures reported earlier The incidence of reported allergic manifestations (16 per cent) in this material is not significantly higher than in a general Swedish population Altogether 12 of the 73 subjects questioned reported some pain or discomfort from one hip Of these 9 (12 per cent) located their troubles to the previously diseased hip In only one patient (1 per cent) was the pain of clinical importance This 35 year old female was the oldest in the material and had a prolonged initial course of the disease as well as a recurrence two years later

At follow up she exhibited a limp restricted motion in several directions and a coxa magna on the radiograms

Of the 67 subjects who personally attended the clinical and radiological follow up 18 exhibited some limitation of motion (10–20) Of these 15 (22 per cent) were restricted in the previously diseased hip giving a statistically significant correlation In only the one female mentioned however was the limitation of motion of clinical importance

The radiological changes seen in the 67 subjects include joint space narrowing caput magnum osteophytes and dense spots in the femoral head cysts and dense spots in the femoral neck and calcifications and os acetabuli near the acetabulum

Since known normal roentgenological standards for the hip in this age group were lacking a separate roentgenographic study has been

included of 72 hips in 36 previously healthy subjects of comparable ages

A comparison between the 67 previously diseased hips and the 72 control hips revealed a statistically significant increase of caput magnum and cysts and dense spots in the femoral neck in the previously diseased hips The same comparison between the 67 previously unaffected hips and the 72 control hips did not show any significant difference The number of hips with three but not one or two different radiological changes was significantly higher among the previously diseased hips than among the control hips

Caput magnum is the probable sequelae of an unspecific irritation to the growing hip joint In this material neither this change nor the cysts and the dense spots in the femoral neck were found to be of importance for pain or restricted motion

The different radiological changes generally discussed as typical of osteoarthritis were either not seen at all in this material (degenerative cysts and sclerosis) or they were equally common in the previously diseased hip and the controls (joint space narrowing and osteophytes)

This 20 year follow up study has demonstrated that the clinical and radiological sequelae of a previous transient synovitis are few and relatively mild

REFERENCES

Adams J A (1963) Transient synovitis of the hip joint in children *J Bone Jt Surg* 45 B 471–476

Colldahl H (1959) Allergiska sjukdomar Thulebolagens skriftserie *Vår Hälsa* no 16

Colldahl, H (1968) Personal communication

Colonna P C (1941) The differential diagnosis of the "painful hip" in childhood *Amer J Surg* 54 609–613

Danielsson L G (1964) Incidence and prognosis of coxarthrosis *Acta orthop scand* Suppl. 66

Emr J (1966) The constitutional and inflammatory etiology of Perthes disease *Beitr Orthop Traum* 13 694–697

Ferguson A B & Howorth B (1934) Coxa plana and related conditions at the hip *J Bone Jt Surg* 16 781–803

Harrison M H Schajowicz F & Trueta, J (1953) Osteoarthritis of the hip A study of the nature and evolution of the disease *J Bone Jt Surg* 35 B 598–626

Hermel M B & Albert S M (1962) Transient synovitis of the hip *Clin Orthop Philadelphia* 22 21–26

Holenstein P (1966) Nachkontrollen bei der transitorischen Synovitis des Hüftgelenks *Z Orthop* 101 392 393

Kraepelin S (1954) The frequency of bronchial asthma in Swedish school children *Acta paediat Uppsala* 43 Suppl 100 149

Lucas L S (1948) *Painful hips in children* (American academy of orthopedic surgeons instructional course lectures) J W Edwards Ann Arbor Mich Vol 5 pp 144–152

McMurray B (1947) A report of six cases of coxa magna following synovitis of the hip joint. *Brit J Radiol* 20 477–481

Murray R O (1965) The aetiology of primary osteoarthritis of the hip *Brit J Radiol* 38 810–824

Rauch S (1940) Transitory synovitis of the hip joint in children *Amer med Ass J Dis Children* 59 1245–1265

Schmid F & Halden L (1949) Die postfetale Differenzierung und Grossenentwicklung der Extremitattenknochenkerne *Fortschr Rontgenstr* 71 975–984

Schmorl G (1931) Anatomische Befunde bei einem Falle von Osteopoikilie *Fortschr Rontgenstr* 44 1–8

Spock, A (1959) Transient synovitis of the hip joint in children *Pediatrics* 1042–1049

Valderrama F J A de (1963) The observation hip syndrome and its late sequelae *J Bone Jt Surg* 45 B 462–470

Acta orthop Scandinav 40 501–506 1969

Department of Orthopaedic Surgery (Head Anders Hulth M D)
Malmo General Hospital University of Lund, Malmo Sweden

THE TIME OF DISABILITY FOLLOWING FRACTURE OF THE SHAFT OF THE TIBIA

Per Edwards & Bo E Nilsson

Received 31 iii 68

The introduction of new methods for internal fixation and early weight bearing in cases of fracture of the shaft of the tibia calls for evaluation of these methods with special regard to the time of disability A review of the literature on the subject gives very little information as to what may be regarded as normal time periods of disability following these injuries The objective of the present study was to examine the time periods of disability as they were recorded in a clinical material consisting of over 500 cases of fracture of the shaft of the tibia

MATERIAL

Available for evaluation were all cases of fracture of the shaft of the tibia over the age of sixteen who were treated at the General Hospital, Malmo 1949–1963 The material included virtually all fractures which had occurred in the city during this time period and, in addition a limited number of cases referred from other parts of southern Sweden

Several heavy industries, including a ship-yard were operating in the city during this time there was also much construction activity and an abundance of automobiles somewhere between that of the United Kingdom and the United States. During the study period the population of the city grew from ca. 200 000 to ca 240 000

Excluded from the study were all cases with combined injuries and a small number in whom the time of disability could not be estimated leaving 380 cases.

METHODS

The time of disability was defined as the interval between the accident and the day f the termination of sickleave A majority of the cases involved in this study were

Financial support was obtained from *The Alfred Österlund Foundation*

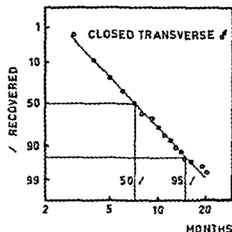


Figure 1 The logarithm of disability time vs percentage of recovered the intervals of the ordinate derived from probit tables (Fisher & Yates 1963) Good adaptation to a straight line implies a normal distribution For the method of calculation see Edwards & Nilsson (1965)

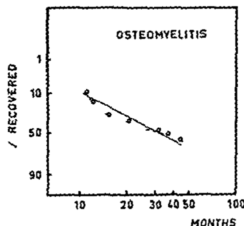


Figure 2 Same as Figure 1 for fractures complicated by osteomyelitis The variables are best interpreted to form a curve function recovery of 95 per cent of the cases is never attained

covered by compulsory national health insurance traffic accident insurance workman s compensation or other accident insurance. This greatly facilitated the evaluation of disability time A number of individuals did not go back to work, the disability time was in these cases regarded as infinite

The presence of cases with an infinite disability time and the fact that disability time was found to form a skewed distribution invalidated the use of average disability time as a basis for comparison between the groups. Instead a method of graphical probit analysis was employed, including a logarithmic transformation of the time scale (Figures 1 and 2) The central tendency of disability time was derived graphically and represents the time period required for 50 per cent of the cases to recover *In addition the time period required for 95 per cent of the cases* was recorded and used as a measure of scatter or as an indication of the absence or presence in the group of cases with an exceptionally long disability time

The time of disability may be compared between the various groups of fractures using a T test of the logarithms of the time values, excluding cases with infinite

time values. In this study differences in central tendencies (the 50 per cent values) of two months or more were significant. Differences of one month were suggestive or non significant.

RESULTS

Longitudinal fractures are here defined as long oblique or spiral fractures usually caused by indirect trauma (Table 1) Transverse fractures including short oblique transverse and/or comminuted fractures were usually caused by direct trauma The latter group has been demonstrated to contain almost all the complications caused by fractures of the shaft of the tibia including osteomyelitis (Edwards 1965) This is true particularly for open injuries that is injuries in which a wound communicates with the fracture Open transverse fractures were found to have a considerably longer period of disability as compared with other types (Table 1) The groups above include only displaced fractures The undisplaced fractures in this study include various types of cases and had the shortest disability time of all

Table 1 Disability time of various fracture types (months)

Type	Males 50%	Males 95%	Females 50%	Females 95%
Displaced without osteomyelitis				
Longitudinal	6	12	6	15
Closed transverse	7	15	9	20
Open transverse	10	29	9	26

Type	Males + females 50%	Males + females 95%
Undisplaced without osteomyelitis	4	9
All types with osteomyelitis	30	∞

Cases with osteomyelitis in this study not more than sixteen were examined separately (Figure 2 Table 1) These cases had an exceedingly long disability time

Definite sex differences were demonstrated only in the group of closed transverse fractures This finding was examined further by comparing the relationship of healing time and disability time between males and females (Figure 3) These two variables were as may be expected correlated It was found that for any given healing time the

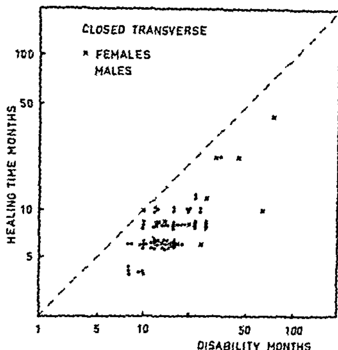


Figure 3 Relationship of disability and fracture healing Note that in this group only one individual went back to work before the fracture was healed There is a positive regression between the variables in both sexes but no difference in slope or intercept between the sexes

time of disability did not differ between females and males (analysis of covariance) Healing time has been demonstrated to be closely related to the severity of the injury (Edward & Nilsson 1965), and it may therefore be concluded that females with closed transverse fractures had generally more severe injuries There is reason to believe that some of the more severe injuries were excluded from the male group together with the combined injuries

In the last three years covered by this study the treatment of transverse fractures was modified Skin incision in the fracture area was avoided and internal fixation was when needed accomplished by blind intramedullary nailing A definite closure of the wound was attained at the time of the primary treatment—skin or muscle grafts were used in cases with threatening necrosis As a result osteomyelitis almost vanished as a complication of tibial shaft fractures In Table 2 the effect of this modification of treatment on the time of disability is shown in males—in females the limited number does not permit a further subdivision of the cases For open transverse fractures the cen

tral tendency of disability time was three months shorter in the latter series There was however a difference also in the group of longitudinal fractures where no systematic changes of the initial treatment had been introduced All the cases regardless of treatment had during the last three years been treated and followed up in a special outpatient clinic and by the same person It appears as if this arrangement *per se* shortened the time required for these cases to go back to work probably because of a more realistic view of their working ability This implies that the need of convalescence had previously been over-estimated

Table 2 Influence on disability time of modified treatment (displaced fractures without osteomyelitis in males time in months)

Type	Control		Modified	
	50%	95%	50%	95%
Longitudinal	7	13	5	10
Closed transverse	8	15	7	13
Open transverse	11	34	8	22

Table 3 Influence on disability time of occupation (displaced fractures without osteomylitis in males time in months)

Demands on ability to stand and walk	50%	95%
Great	8	14
Small or average	8	18

In about one third of the males their ordinary occupation included heavy labour or otherwise strong demands on their ability to stand and walk When these cases were compared with the rest there was no significant difference in the central tendencies (Table 3) However the 95 per cent value was less in the heavy labour group This again may be the result of excluding the combined injuries particularly from the group with heavy labour Between individuals with small and average demands on standing and walking ability there were no differences in disability time It must be concluded that occupation does not substantially influence the time period required for these patients to go back to work

SUMMARY AND CONCLUSIONS

The time period required to recover from fracture of the shaft of the tibia was examined The type of trauma as reflected in fracture type was found to influence the time of disability When the severity of the injury had been taken into account, there were no significant differences between the sexes nor were there any differences that could be related to occupation When the injuries were managed in a special clinic the interval required for these cases to go back to their normal activities was shortened

REFERENCES

Edwards P (1965) Fracture of the shaft of the tibia 492 consecutive cases in adults *Acta orthop scand* Suppl 76

Edwards P & Nilsson B L (1965) Graphic representation of healing time in fractures of the shaft of the tibia *Acta orthop scand* 36 104

Fisher R A & Yates F (1963) *Statistical tables* Hafner Publ Co Inc New York.

Acta orthop Scandinav 40 507–519 1969

Department of Orthopaedic Surgery (Chief Prof T Hierton) and the Department of Paediatrics Section of Paediatric Neurology (Chief B Hagberg) University Hospital, Uppsala Sweden.

ACHILLES TENOPLASTY FOR CORRECTION OF EQUINUS DEFORMITY IN SPASTIC SYNDROMES OF CEREBRAL PALSY

R Lemperg B Hagberg & A Lundberg

Received 18 iv 68

Equinus deformity of the foot in walking is the most common mal position in the lower extremity in children with spastic syndromes of *cerebral palsy Usually this deformity is not an isolated symptom but* part of a complex motor disturbance due to abnormally increased stretch reflexes and muscle imbalance Physical treatment redression and plaster fixation are sometimes insufficient and patients and parents are unwilling to use splints and braces Moreover attempts to correct the foot passively against a tight achilles tendon may result in deformity of the forefoot and valgus of the heel (Eggers & Evans 1963)

It is now generally accepted that surgical treatment of the foot equinus in carefully selected cases with a spastic CP syndrome may be beneficial for gaining function improving the child s motor de velopment and preventing secondary deformities However divergent opinions still exist as to selection of suitable candidates for operation optimal age and advisable type of operative procedure in individual cases Since the first attempt of Little (1854) the single procedure most frequently used for treatment of contracture or spasticity of the triceps surae has been *elongation of the achilles tendon Tenoplasties were generally found to give more satisfactory results whereas simple* subcutaneous tenotomies as a rule were condemned (Hodgen & Franz 1938 McCarrol & Schwartzmann 1942 Lange 1962 Keats 1965)

Equinus relapse as well as occurrence or risk of disabling calcaneus deformity due to overcorrection gave rise to a number of modifications of the original Z plasty procedures (White 1943 Cummins et al 1946 Baker 1956 Banks & Green 1958) In order to overcome some dis

advantages of the tendon elongation procedure, Vulpius (1913) and Strayer (1950 1958) introduced selective elongation of the gastrocnemius aponeurosis whereas Silfverskiold (1924) carried out recession of the gastrocnemius insertions from the femur for the treatment of spastic foot equinus

The aim of this communication is to present results of 48 consecutive elongations of the achilles tendon by a modified sliding Z plasty made on 32 children with equinus deformity due to a spastic CP syndrome These results will be discussed and compared with those obtained by gastrocnemius recession (Silfverskiold s procedure 1924) in an earlier and very similar clinical material published in detail elsewhere (Hagberg Lemperg & Lundberg 1968)

CLINICAL MATERIAL

32 children 2 to 14 years of age with cerebral palsy were operated on Altogether 48 operations were performed The CP syndromes were classified as described by d Avignon et al (1960) Of the 32 children 26 were shown to have spastic diplegia 5 of these combined with ataxia Five had spastic hemiplegia, one combined with slight ataxia Finally one suffered from athetoid movements Special efforts were made to ensure the diagnosis dystonic tetraplegic syndrome without any real spasticity in which achilles tendon elongation might lead to calcaneus deformity

11 patients (16 legs) had been operated on previously on an average 3 0 years earlier by Silfverskiold s method (gastrocnemius recession) Intrapelvine obturator nerve resection had been performed on 8 patients (16 legs) on an average 3 5 years earlier Finally partial hamstring transfer had been done in 3 cases in one of them 6 years in one 4 years earlier In one patient this operation had been performed bilaterally at the same time as the achilles tendon elongation

All patients had preoperative physical training at repeated periods for at least one year at the paediatric clinic or at a special institute for CP children (Folke Bernadottehemmet Uppsala) This made it possible to evaluate the motor handicaps several times to follow their development, and to discuss and evaluate the indications for operative treatment with the paediatricians

Evaluation of Equinus Deformity

The foot equinus was evaluated with and without shoes whilst standing walking and if possible running It was noted if the heel struck the floor without compensatory recurvation of the knee joint valgus of the heel or abduction of the forefoot In the *supine* position the classical test (Silfverskiold) for equinus was carried out with the knee joint flexed at 90 and extended The last mentioned test if positive, is thought to be significant for the exclusive shortening of the gastrocnemius portion of the triceps surae (positive Silfverskiold s test)

An attempt was made to obtain a better understanding of the extent to which the gastrocnemius and soleus respectively contributed in weight bearing as well as in their function as antigravitation muscles to the equinus in spastic CP syndromes It could be observed in a number of patients that after a period of quiet standing the heel reaches the floor whilst the knee joint is straight Even with a slight flexing of the knee the heel immediately rises from the floor and the foot then remains in equinus even if the knee is flexed 90 (It is necessary to support the buttocks when performing this test) This observation could also be made in those patients who had a positive Silfverskiöld s test in the supine position which suggests that the gastrocnemius is the offending muscle producing equinus This indicates however that the soleus functioning as antigravitation muscle may induce equinus which it need not do in the supine position There is a further source of error to be taken into account in evaluating the equinus in the supine position the calcaneus may move into valgus during passive dorsiflexion of the foot and therefore mask the equinus

Efforts were made to evaluate the function and eventual pareses of the *foot extensors* Good function of the extensors was taken to indicate that the achilles tendon should not be elongated more than required to bring the foot to a right angle at operation

Indication for Operation

Operation of the equinus deformity was *considered* when continuous physical treatment gave no improvement or if progress of the deformity was obvious *Indication* for operation was estimated to be present if the equinus was found (A) to be a serious obstacle to standing or walking ability and (B) to give rise to secondary deformities or malposition of the foot or the whole lower extremity The total motor pattern was always evaluated and patients lacking enough motor development for walking or an acceptable sense of balance were excluded from operation Deformities around the hip and knee joints had usually been corrected before if they interfered with function Mental retardation was not considered to be a contra indication against operation

During the last 2–3 years feet with a more pronounced valgus of the heel and abduction of the forefoot were excluded from achilles tendon elongation alone and primarily treated with stabilization of the subtalar joints Practically no other operative method was used for treat

ment of equinus deformity while this series was selected, whether Silfverskiold's test was found to be positive or not

Surgical Procedure

A sliding Z plasty of the achilles tendon was performed identically in all cases Figure 1A illustrates the incision of the tendon in the frontal plane which is carried proximally to the ventral muscle fibres of the triceps The knee joint is then brought to an exactly straight position and the foot slowly dorsiflexed to 90 with the calcaneus in the right position at the same time possible tight muscle and tendon fibres on the ventral side including the plantaris tendon are dissected This operation can be done without interrupting the continuity of the muscle tendon and without touching the loose connective tissue between the tendon and the dorsal surface of the tibia, thus avoiding scar tissue in this region The length of the incision in the tendon is usually about 6–10 cm and the lengthening of the tendon necessary for correcting the equinus approximately 2–3 cm Thus a large contact surface of the cut in the tendon is obtained (Figure 1B) The tendon is sutured with 003 steel wire with 10–12 interrupted sutures After suturing the tendon it should not be possible to dorsiflex the foot more than 5–10 degrees with a straight knee otherwise the tendon must be resutured under greater tension Peritendineum and subcutaneous tissue are sutured simultaneously with fine catgut the skin with steel wire Complete haemostasis is essential

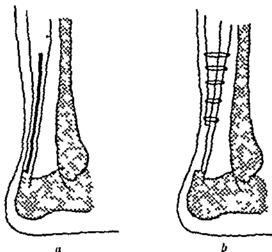


Figure 1a The incision in the achilles tendon in the frontal plane is marked by uninterrupted line where the tendon is completely divided The dotted line indicates where the ventral fibres of the triceps are only partially dissected

Figure 1b After dorsiflexing the foot to the right angle the tendon is adapted and sutured with 10–12 interrupted steel wire sutures at a tension which does not allow a dorsiflexion of the foot of more than 5–10 after completing the suture

The leg including the thigh is put in a plaster—the knee joint flexed about 10 and the foot in neutral position This leg position is more comfortable for the patient than a straight knee joint and maximal dorsiflexed foot It avoids pressure on the skin decreases tension in the tendon suture and does not interfere with the final result This plaster is exchanged after 3 weeks for a short walking cast which is kept for a further 2–3 weeks

In those cases where the equinus was completely released during anæsthesia it was more difficult to get a correct idea as to how much the tendon should be elongated Some guidance can be obtained by evaluating the degree of equinus by observation of the heel—floor distance in standing and walking It is advisable in these cases however to limit the elongation to approximately 2 cm this has proved to be sufficient to overcome even equinus of obviously higher degree

Capsulotomia for correcting the equinus was never necessary Rerouting of the tibialis posterior tendon as described by Baker & Hill (1964) was carried out in 3 cases simultaneously with the achilles tendon procedure All operations except two were performed by one surgeon

Postoperative Treatment

After removal of the plaster the children were treated with physiotherapy to strengthen the dorsiflexors and walking exercises This treatment was given first at the paediatric department and then continued without interruption during the whole observation period if possible with 2–3 periods of 2–3 weeks a year hospitalization A splint was used until normal weight bearing was achieved and then discarded if there were no other deformities requiring the use of splints During the continuous follow up in this series in no case was it necessary to re apply splints for treatment of incidental recurrence of the equinus

RESULTS

Estimating the results of a single operative procedure in children with a CP syndrome is a difficult undertaking owing to the manifold factors influencing the clinical picture The general motor pattern might be altered by mental and physical development and additional treatment after the operation The results in this study were therefore not classified primarily by subjective definitions such as excellent good etc

Table 1 Comparison of results of achilles tendon elongation and gastrocnemius recession in age groups 2–7 and 7–14 years at operation

			The appearance of the foot under gait or weight bearing						
	No of cases	No of feet	Mean observ time (yrs)	Heel on floor[b]	Heel on floor[c]	Ball heel gait	Valgus def	Varus def	Poor results
Achilles tendon elongation									
2–7 years	16	24	2 2	24	–	2	17	–	3[d]
7–14 years	16	24	2 0	24	–	–	18	–	3[e]
Gastrocnemius recession									
2–7 years	19	28	2 5	8	2	3	14	6	18[d]
7–14 years	11	15	4 6	4	1	–	6	4	9[d]

These results have been reported in detail elsewhere (Hagberg, Lemperg & Lundberg 1968)

[b] Without hyperextension of the knee joint

With hyperextension of the knee joint

[d] Persisting equinus

No improvement of foot deformity by operation (extensive valgus abduction deformity)

nor by comparative terms such as improved worsened etc Instead registration of deformities of the foot and knee joint observed in walking or in cases unable to walk in standing was used In order to get the greatest possible objectivity the results were assessed both by the paediatrician and the operating orthopaedic surgeon The patient material was divided into two age groups at operation one group 2–7 years comprising 16 patients with 24 operations and the other 7–14 years comprising 16 cases with 24 operations Median observation time for the whole group was 2 1 years for the younger age group 2 2 and for the older 2 0

In Table 1 postoperative observations made concerning the equinus and other deformities which were usually present are summarized Equinus was found in three feet (3 patients with diagnosis spastic diplegia) classified as poor results all of them due to primary insufficient elongation of the tendon at operation (Table 2) One case required reoperation with another achilles tendon elongation 3 years later The other two had a mild deformity which did not interfere with their ability to walk with shoes and as yet showed no tendency for progress In one of these cases no equinus could be found in the supine

Table 2 Factors negatively influencing the results in cases classified as 'poor' after operative treatment of equinus deformity of the foot in children with a spastic CP syndrome

	Achilles tendon elongation	Gastrocnemius resession
Total number of procedures	48	43
Total no of poor results (feet)	6	27
Equinus at removal of postoperative plaster after 6 weeks	3	5
Later relapse of equinus	–	2[a]
No improvement of foot deformity (valgus abduction)	3	1
Hyperextension of knee joint without equinus	2	4
Hyperextension of knee joint with equinus	1	3
Reoperation due to equinus	1	16
Calcaneus deformity	–	–

Both cases are re operations after previous gastrocnemius recession and showed hyperextension of the knee joint before achilles tendon elongation

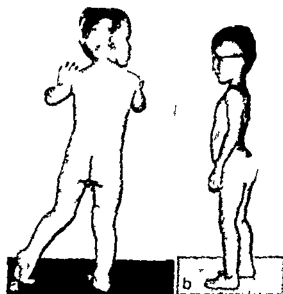


Figure 2a 4 year old boy with a spastic diplegia with left side dominance showing a considerable foot equinus and inward rotation of the leg in standing and walking

Figure 2b The same patient as in Figure 2a 1 year and 10 months after achilles tenoplasty on the left side In standing there is no equinus and the heel touches the floor without hyperextension of the knee The result was however ranged as poor because in walking without shoes he showed equinus and slight hyperextension of the knee

position or in standing as can be seen in Figure 2B In walking without shoes however he showed equinus and slight hyperextension of the knee joint which was also present preoperatively

In three more feet (2 patients) classified as poor results tendon elongation gave no improvement of the foot deformities which showed a masked equinus combined with extensive valgus of the heel and abduction of the forefoot Both patients had a diagnosis of ataxic diplegia, in one of them combined with infantile hydrocephalus They were later treated with a triarticular subtalar arthrodesis

Of the other 42 feet 40 required no further surgical treatment for foot deformity during the follow up period and two were operated on for hallux valgus 35 feet showed valgus deformity of slighter degree Of the 16 feet (11 patients) previously treated insufficiently with gastrocnemius recession (Silfverskiold s procedure) 15 showed no equinus One was among those mentioned above as poor results due to valgus abduction deformity Four cases hyperextended their knee joints preoperatively Two of them showed the same deformity postoperatively whereas two walked without hyperextension (Table 2)

Adhesions between skin and tendon interfering with function or migration of the steelwire sutures did not occur in any case No postoperative complications occurred

Table 3 Results reported by different authors after operations for equinus deformity of the foot in patients with cerebral palsy

The definition positive covers discernments as excellent good fair improved etc and negative poor worse unimproved The significance of positive and negative is *not* directly comparable between different authors

	Achilles tendon elongation				Gastrocnemius procedures†			
	No of procedures	Positive results	Negative results	Re op for equinus	No of procedures	Positive results	Negative results	Re op for equinus
Green & McDermott (1942)	125	83	24	6	19 b c	13	6	?
McCarroll & Schwartzmann (1943)	10[illegible]	85	12	?	174 b	112	51	?
Phelps (1957)	121	25	?	?	59 b	6	?	?
Banks & Green (1958)	164	148	14	6	36 a b c	26	10	13
Strayer (1958)	–	–	–	–	23 d	18	5	?
Silver & Simon (1959)	–	–	–	–	110 c	105	f	?
Pollock (1962)	128	70	6	1	12 d	10	2	?
Hagberg Lemperg & Lundberg (1968)	48	4[illegible]	6	1	43 a	16	27	16

The total number of feet given in the result columns does not always correspond to the number of operated feet due to loss of patients at follow up and to lack of specifications

Controlled elongation of the achilles tendon

† Includes (a) recession of gastrocnemius insertions from femoral condyles (b) total or partial neurectomy of the motor branches to the gastrocnemius (c) a combination of a and b (d) lengthening of gastrocnemius aponeurosis

average of 2 years earlier for equinus deformity of the foot Spastic diplegia was present in 26 cases five with additional ataxia 5 had spastic hemiplegia one of these additional ataxia and one case had athetoid dyskinesia The age at operation was in 24 instances between 2–7 and in 24 between 7–14 years Mean observation time was 2 1 years range 1–4 years In 16 feet gastrocnemius recession had been carried out on an average 3 years previously

The effect upon the equinus deformity, estimated during walking or weight bearing was clearly satisfactory in 42 instances This was also true in those cases which had previously been inadequately treated with gastrocnemius recession In three instances (3 patients) insufficient elongation of the tendon was the cause of persistent equinus One of them had to be re operated In three other limbs (two patients) no improvement of the foot deformity equinus valgus abductus was obtained these patients having an atactic diplegia with the characteristic hypotonic muscular insufficiency of this syndrome These three failures must be attributed to wrong indication for operation and do not influence the merits of this operation Calcaneus deformity never occurred

In children with a definite and purely spastic CP syndrome independently of age achilles tendon elongation in our hands proved to be a reliable and safe procedure for treatment of equinus deformity provided the operation had been executed correctly and the patients had been selected carefully

REFERENCES

d Avignon M Bille B Hagberg B & Olow J (1960) Klinisk klassificering av CP syndromen hos barn *Svenska Lak Tidn* 57 2533

Baker L D (1956) A rational approach to the surgical needs of the cerebral palsy patient *J Bone Jt Surg* 38A 313

Baker L D & Hill L M (1964) Foot alignment in the cerebral palsy patient *J Bone Jt Surg* 46A 1

Banks H H & Green W T (1958) The correction of equinus deformity in cerebral palsy *J Bone Jt Surg* 40A 1359

Cozen L (1966) Effect of lengthening the achilles tendon on the strength of gastrocnemius soleus musculature *Clin Orthop* 49 179

Cummins E J Anson B J Carr B W & Wright R R (1946) The structure of the calcaneal tendon (of achilles) in relation to orthopedic surgery *Surg Gynec Obstet* 83 107

Eggers G W N & Evans E B (1963) Surgery in cerebral palsy *J B ne Jt Surg* 45A 1275

Green W T & McDermott L J (1942) Operative treatment of cerebral palsy of spastic type J A M A 118 434

Hagberg B Lemperg R. & Lundberg A (1968) Transposition av gastrocnemius muskulaturen vid spastiska former av cerebral pares hos barn *Nord med* 79 685

Hodgen J T & Frantz C. H. (1938) Subcutaneous tenotomy of the achilles tendon. *J Bone Jt Surg* 20 419

Keats S (1965) *Cerebral palsy* Charles C Thomas Springfield, Ill

Lange M (1962) *Orthopadisch—Chirurgische Operationslehre* 2 Auflage Bergmann, Munchen

McCarrol H. R & Schwartzman J P (1943) Spastic paralysis and allied disorders *J Bone Jt Surg* 25 745

Phelps W M (1957) Long term results of orthopaedic surgery in cerebral palsy *J Bone Jt Surg* 39A 53

Pollock, G A (1962) Surgical treatment of cerebral palsy *J Bone Jt Surg* 44B 68

Pollock, G A & English T A (1967) Transplantation of the hamstring muscles in cerebral palsy *J Bone Jt Surg* 49B 80

Silfverskiold N (1924) Reduction of the uncrossed two joint muscles of the leg to one joint muscles in spastic conditions. *Acta chir scand* 56 315

Silver C. M & Simon S D (1959) Gastrocnemius muscle recession (Silfverskiold operation) for spastic equinus deformity in cerebral palsy *J Bone Jt Surg* 41A 1021

Strayer L. M (1950) Recession of the gastrocnemius. An operation to relieve spastic contracture of the calf muscles *J Bone Jt Surg* 32A 671

Strayer L. M (1958) Gastrocnemius recession *J Bone Jt Surg* 40A 1019

Vulpius O & Stoffel A (1913) *Orthopadische Operationslehre* Ld I pp 29–31 Stuttgart Ferdinand Enke

White J W (1943) Torsion of the achilles tendon its surgical significance *Arch Surg* 46 784

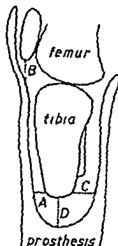


Figure 2 *A* *Distance between anterior tibial ridge and socket* *B* *Distance between patella and socket* *C* *Distance between posterior tibial ridge and socket* *D* *Distance between tibial ridge and socket*

and the occurrence of pain on weight bearing was noted The doctor's opinion as to the fit of the prosthesis during walking the presence of swelling of the stump and any pressure manifestations (redness discoloration hyperkeratosis) or other skin changes on the stump corresponding especially to the measurement sites A B and D were recorded as shown in Table 1 The length of the amputation stump was measured on the tibia.

RESULTS

Clinical Results

The clinical observations are presented in Table 1 and the results of the measurements on the X ray films in Figure 3 It can be seen in the Table that 13 (54 per cent) of the 24 patients considered the stability of the prosthesis to be good and 11 (46 per cent) considered it to be moderate or poor The examining doctor considered 16 (67 per cent) of the prostheses to be too large and of these 16 patients 11 had pressure manifestations on the stump 9 on the region over the patella tendon and 9 over the end of the stump and/or the anterior ridge of the tibia In 8 patients the prosthesis was considered to fit well of these 4 showed pressure manifestations on the stump Three of these 8 prostheses had been worn for only 2 weeks and none of these three patients showed pressure manifestations on the stump

Roentgenological Results

Figure 3 shows the changes in the distances between certain points on the stump and the socket of the prosthesis under the four different weight bearing conditions a–d Some distances are not given in the

Table 1 Below-knee amputees with PTB prostheses The patient's opinion as to the stability of the prosthesis and the doctor's opinion of its fit during walking are noted The letters A B and D indicate the signs of pressure on the amputation stump at points corresponding to the distances A B and D shown in Figure 2.

Patient no	Use of present prosthesis (mths)	Pain during walking	Patient's opinion of walking stability: Good	Fair	Poor	Doctor's judgment on fitting: Good	Too big	Stump swelling present	Pressure signs on stump at points: A	B	D	Length of tibia (cm)
1	1	+	+			+		—	—	—	—	16
2	½	+	+			+		+	—	—	—	15
3	24	—		+			+	—	—	—	+	20
4	6	—	+				—	—	+	+	+	16
5	3	—	+			+		+	—	—	—	11
6	24	—		+			+	—	+	+	—	16
7	24	—		+		+		+	—	+	—	22
8	12	—	+				+	—	—	—	—	22
9	12	—	+				+	+	—	—	+	20
10	12	—	+				+	—	—	—	—	22
11	18	—			+		+	+	+	+	+	22
12	24	+		+			+	—	+	+	+	11
13	12	—		+			+	—	—	—	—	15
14	6	+	+				+	—	—	+	—	14
15	12	—		+			+	+	+	+	+	15
16	2	—	+			+		—	—	—	—	11
17	18	—		+			+	—	—	—	+	14
18	24	—		+			+	—	+	+	—	13
19	30	—	+			+		—	—	—	—	18
20	3	—	+			+		—	—	—	—	14
21	6	—			+		+	—	—	+	—	11
22	6	—		+			+	+	+	+	+	18
23	12	—	+				+	—	—	—	—	11
24	¼	—	+			+		+	—	—	—	15

Figure these were excluded for technical reasons Distance A (anterior ridge of tibia to socket) varied by a few millimeters in 8 patients under all four weight bearing conditions In the remainder the changes be tween conditions a and b were found to be up to 20 mm Distance B (patella to socket) varied by less than 1 cm in the different positions in all patients except one (No 21) In some cases distance C (posterior distal ridge of tibia to socket) showed greater variations than distance

Figure 3 For each individual patient the distances measured on the X ray films (A–D Figure 2) are represented graphically under the four conditions of weight bearing (a–d Figure 1) The scale on the vertical line is cm

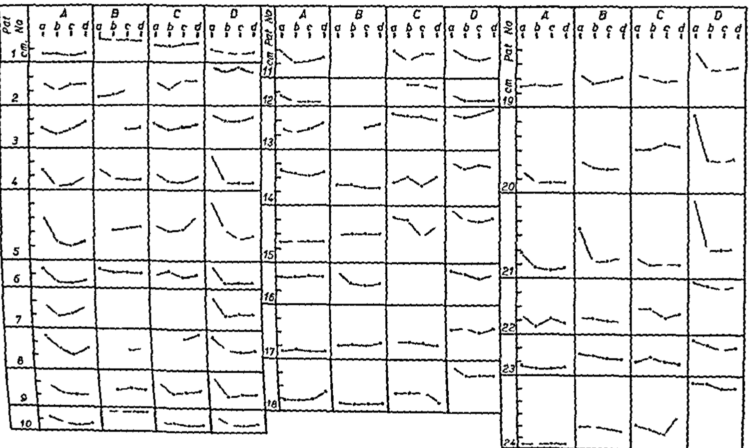
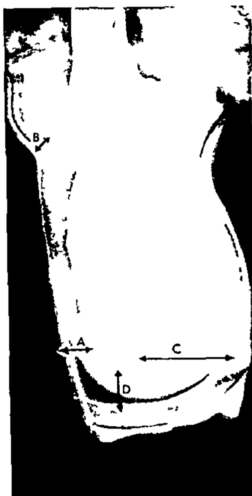


Figure 4 The roentgenogram shows the prosthesis in position C stump skeleton and soft tissue and the degree of contact between the stump and prosthesis is shown A B C and D indicate the distances as in Figure 2



A in the same patient (Nos 15 and 24) Furthermore under condition d it often showed a different change from that in distance A Distance D (distal end of tibia to base of socket) showed the greatest changes between conditions a and b–d In some cases the changes of distance D clearly exceeded those of distances A–C in the same patient The changes of all distances under conditions b–d were small throughout with a few exceptions for condition d in distance C

Not only the movements between the skeletal stump and the prosthesis but also the very frequent bad contact between the soft tissue of the stump and the prosthesis was shown on radiograms Figure 4

Correlation between Clinical and Roentgenological Findings
(Table 1 and Figure 3)

1 *Patient's opinion on the stability of the prosthesis* Of the 13 patients who considered the stability of the prosthesis to be good 7 showed movements between the stump and socket which exceeded 1 cm at one of the measurement sites in most cases distance D The change in distance B was small throughout in all 13 patients Of 9 patients who considered the stability of the prosthesis to be moderate 4 showed movements exceeding 1 cm at one measurement site, but not greater than in any of the patients who considered the stability to be good In one of the 2 patients who considered the stability of the prosthesis to be poor there was considerable movement with changes in all distances In the other patient the changes were relatively small Thus there was no correlation between the patient s opinion of the stability of the prosthesis and the roentgenologically measured movement between the stump and the prosthesis socket

2 *Doctor s opinion on the fit of the prosthesis* Of 16 patients whose prostheses were considered by the doctor to be too large 8 were found to have movements exceeding 1 cm at one of the measurement sites whereas the others showed no changes in the position of the prosthesis Thus there was no correlation in this respect

3 *Pressure manifestations and skin changes on the stump* In 7 of the 8 patients who had pressure manifestations over the anterior distal ridge of the tibia distance A was less than 1 cm when the body weight was borne by the prosthesis leg only Two of these patients had used their prostheses for only 2 weeks and one of them complained of pain when bearing weight on the prosthesis

Pressure manifestations or skin changes over the region of the patella tendon showed no correlation to any type of change of any of the distances Ten patients had skin changes on the end of the stump in two of these the distance D changed by less than 1 cm when the body weight was borne by the prosthesis leg only (condition c) and in 5 the movement was relatively pronounced

As can also be seen in Table 1 and Figure 3 pain on weight bearing was reported by 4 patients and in all of these the movements between the stump and socket were very small It was found further that any swelling of the stump that occurred had no correlation with the fit of the prosthesis The length of the stump did not appear to have any correlation with the patient s opinion on the stability of the prosthesis

nor with the occurrence of skin changes or pressure manifestations on the stump

DISCUSSION

Below knee amputees fitted with a PTB prosthesis often experience a sensation of instability when walking In this study the movement of the stump in relation to the PTB prosthesis was studied by a roentgenological method under four different conditions of weight bearing An attempt was made to correlate the roentgenological findings to the patient s opinion on the stability of the prosthesis pain when bearing weight on the prosthesis the doctor s opinion on the fit of the prosthesis and the occurrence of pressure manifestations on the amputation stump The patients can be considered representative of those encountered daily by an orthopedic surgeon but allow no close analysis over and above that of the problems defined for this investigation

The roentgenological technique used permitted evaluation of the relation of the stump bone to the socket of the prosthesis but only limited possibilities of direct evaluation of any compression of the soft tissues The roentgenological examination gave a good idea of the movement of the stump bone in relation to the socket of the prosthesis under different conditions of weight bearing and thereby also of the fit of the prosthesis It showed that "total contact between the socket and stump was maintained in only a few cases and that in most patients considerable movement between the stump and socket took place under different conditions of weight bearing No clear correlation was found however between the roentgenologically demonstrated movements and the patient s opinion on the stability of the prosthesis or the opinion of the doctor on the fit of the prosthesis This may possibly be due to the fact that the tolerance limit for such movements is unknown and that the individual judgments of stability and sensations of uncertainty on walking with a prosthesis can also vary considerably between different patients

Pressure manifestations on the amputation stump over the region of the anterior ridge of the tibia were more common when during weight bearing on the prosthesis the distance between the distal anterior ridge of the tibia and the socket of the prosthesis was less than one cm The difference between a stump bearing no weight and a stump bearing full body weight was most pronounced in patients 4 5 9 15 19 20 and 21 None of them had pain on walking but 5 of the 7 had pressure changes on the distal part of the stump

Correlation between Clinical and Roentgenological Findings
(Table 1 and Figure 3)

1 *Patient's opinion on the stability of the prosthesis* Of the 13 patients who considered the stability of the prosthesis to be good 7 showed movements between the stump and socket which exceeded 1 cm at one of the measurement sites in most cases distance D The change in distance B was small throughout in all 13 patients Of 9 patients who considered the stability of the prosthesis to be moderate 4 showed movements exceeding 1 cm at one measurement site but not greater than in any of the patients who considered the stability to be good In one of the 2 patients who considered the stability of the prosthesis to be poor, there was considerable movement with changes in all distances In the other patient the changes were relatively small Thus there was no correlation between the patient s opinion of the stability of the prosthesis and the roentgenologically measured movement between the stump and the prosthesis socket

2 *Doctor's opinion on the fit of the prosthesis* Of 16 patients whose prostheses were considered by the doctor to be too large 8 were found to have movements exceeding 1 cm at one of the measurement sites whereas the others showed no changes in the position of the prosthesis Thus there was no correlation in this respect

3 *Pressure manifestations and skin changes on the stump* In 7 of the 8 patients who had pressure manifestations over the anterior distal ridge of the tibia distance A was less than 1 cm when the body weight was borne by the prosthesis leg only Two of these patients had used their prostheses for only 2 weeks and one of them complained of pain when bearing weight on the prosthesis

Pressure manifestations or skin changes over the region of the patella tendon showed no correlation to any type of change of any of the distances Ten patients had skin changes on the end of the stump in two of these the distance D changed by less than 1 cm when the body weight was borne by the prosthesis leg only (condition c) and in 5 the movement was relatively pronounced

As can also be seen in Table 1 and Figure 3 pain on weight bearing was reported by 4 patients and in all of these the movements between the stump and socket were very small It was found further that any swelling of the stump that occurred had no correlation with the fit of the prosthesis The length of the stump did not appear to have any correlation with the patient s opinion on the stability of the prosthesis

4 There were signs indicating that a small amount of movement between the stump and socket increases the comfort of the patient and prevents pressure manifestations on the stump

REFERENCES

Bleck, E. E. Canty T J & Doolittle R. C. (1963) Below the knee closed end soft socket *J Bone Jt Surg* 45 967–976

Lemperg R. (1965) Protesforsorjning av amputerade i Sverige och Algeriet. *Sv Lakartidn* 41 3336

Radcliffe C. W & Fort, J (1961) *The patella tendon bearing below knee prosthesis* Biomechanics Laboratories Univ of California Berkely

Acta orthop Scandinav 40, 530-542 1969

From the Orthopaedic Clinic Lund, Sweden (Head Prof Gunnar Wiberg)

FRACTURE OF THE CALCANEUS

A Review of 110 Fractures

MOHAMMED ZAYER

Received 2 iii 68

Fracture of the calcaneus is liable to be followed by a varying degree of disability according to the type of the fracture Differences in the classification of fracture of the calcaneus have resulted in a considerable divergence of the results obtained by various methods of treatment Comparison of series published by different authors is therefore difficult Most classifications are based on anatomical grounds (*Ahlberg* 1940 *Widen* 1954 *Arnesen* 1958, *Graham Aply* 1959 *Watson Jones* 1960 and *Thorén* 1964) sometimes in combination with aetiological factors (*Palmer* 1948 and others)

The anatomical classifications distinguish mainly between extra articular and intra articular fractures of the calcaneus *Ahlberg* (1940), who recognised 3 types found the fractures to be extra articular in 14 per cent, intra articular without dislocation in 8 per cent and intra articular with dislocation in 78 per cent *Watson-Jones* used largely the same classification with differentiation between fractures with and without involvement of the subtaloid joint and subgrouping of these two main types

The treatment can be closed or open

CLOSED TREATMENT

This group includes a) expectant or no treatment (*Eastwood* 1938) b) primary manipulative reduction (*Hauser* 1945 *Norman* 1946, *Essex & Lopresty* 1952 *Thoren* 1964) c) immobilisation for varying period in plaster possibly after manipulation (*Dachtler* 1931 *Scheler* 1939 *Ahlberg* 1940 *Golasch* 1941 *Hullinger* 1944 *Raisman* 1944 *van de Marl & MacCarthy* 1946 *Gellman* 1951, *Astrup* 1952 *Platt* 1956 *Dell* 1958 *Lebhart* 1959) and d) traction (*Gelinsky* 1913 *Bohler* 1929

Jackie & Clark 1936, *Arnesen* 1939 *MacAusland* 1941, *McBride* 1944 *Harris & Gill* 1944) In Sweden *Thoren* (1964) warmly recommended primary manipulation On the basis of his series of 121 cases of extra articular fracture without or with only moderate dislocation he concluded that such fractures should be treated primarily with manipulation and that though good results may obtained by open reduction in cases with severe dislocation satisfactory results can also be achieved by manipulation

OPEN TREATMENT

Surgical treatment may consist of open reduction possibly with osteosynthesis or of subtaloid or triple arthrodesis Operations such as astragalectomy (*Destot* 1902 *Soubeyran & Rives* 1913) calcanectomy *Leriche* 1913 *Pridie* 1946) osteotomy of the calcaneus (*Ashurst* 1921 and *Danis* 1951) and denervation of the subtaloid joints (*Tavernier & Godinot* 1945 and *Sallick & Blum* 1948) for correction of deformaties after fractures of the calcaneus fall beyond the scope of the present investigation and will not be discussed here

Open reduction possibly with osteosynthesis has been performed by *Eisendrath* (1905) *Juvara* (1911) *Beesly & Price* (1914) *Leriche* (1922) *Simon & Stultz* (1928) *Moony* (1935) *Lang* (1939) *Cherry* (1947) *Palmer* (1948) *Widen* (1954)

Widen (1954) reported a series of 221 fractures of the calcaneus of which 167 were after examined Of these 75 had been treated by open reduction and 92 by conservative methods including manipulation Widén had the impression that if there is little or no dislocation of the subtaloid joint treatment should be conservative Cases with intra articular fracture including depression of the lateral part of the posterior joint facet should be treated with open reduction Severe comminuted fractures and cases where open reduction has proved unsuccessful should probably be treated with primary triple arthrodesis

Triple arthrodesis or subtaloid arthrodesis has been used either as primary treatment i e performed within one week of the accident (*van Stockum* 1912 *Wilson* 1927 *Nove Josserand* 1928 *Hosford* 1936 *Harris* 1946 1963 *Colonna* 1950 *Mandruzzato* 1951 *Gollasch* 1953 *Brattstrom* 1953 *Thompson & Friesen* 1959) or as secondary treatment i e 3–6 weeks after the injury (*Monod* 1920 *Bartley* 1931 *Conn* 1935 *Moberg & Erfors* 1953 and *Watson-Jones* 1960)

PRESENT MATERIAL

The material consisted of all fractures of the calcaneus treated at the Department of Orthopaedics University Hospital Lund between 1939 and 1961 Treatment was not uniform but more than half of the patients had been subjected to primary subtaloid arthrodesis or to triple arthrodesis.

The classification is according to *Widén* but with the following modification

Figure 1

Type A

Group I Fracture of the posterior superior part of the tuberosity



Group II Fracture of the medial tubercle



Group III Fracture of the sustentaculum



Group IV Fracture of the anterior process



Group V Extra articular fracture and intra articular fracture without displacement of joint fragments



Type B

Group VI Intra-articular fracture with depression of lateral part of posterior articular surface. (Either the fragment has the same extension in length as the post artic sur face—type 1 or even it includes the upper portion of the tuberosity—type 2



Group VII Intra articular fracture with depression of the whole or bulk of the post. artic surface (Either the whole of the post artic. surface was depressed in one piece—type 1 or the various fragments— each depressed separately—type 2



(Figure 1) *Widen*s classification distinguishes 2 main types type A (extra articular) with groups I–IV and type B (intra articular) with groups V–VII Since his group V (type B) comprises fractures without dislocation it is hardly likely to result in such severe disability as the cases in groups VI and VII and group V therefore was included with the less severe cases in type A (see Figure 1)

The present series comprised 123 patients with all together 142 fractures of the calcaneus. Of these patients 94 with 110 fractures were reviewed in 1962 As to the remaining 29 patients, 15 had died 4 were still receiving treatment, 1 was in a mental hospital, 1 was in prison and 8 could not be traced. Of the 123 patients 22 8 per cent were females which is somewhat higher than the figures given for other series (*Eiken* 7 7 per cent *Ahlberg* 14 4 per cent, *Widén* 20 5 per cent) The ages of the patients at the time of the accidents ranged from 12 to 87 The frequency was highest for the years between 40 and 60 (Figures 2 and 3) in which 61 (50 per cent) of the fractures had occurred Of the 142 fractures, 49 per cent were left unilateral, 36 per cent were right unilateral and 15 per cent were bilateral.

As expected fairly many of the patients had occupations involving a risk of falling from a height Thus, 27 were builders or painters But the number of women who had sustained the fracture at home was also fairly high *viz* 20 They had fallen from a table or from the window when cleaning the windows etc The next largest groups (11 patients) consisted of farm labourers. The remaining patients had various occupations

As many as 82 of the fractures were due to fall from a height. The height varied between 1 and 3 metres. In 10 cases the patients had fallen from a ladder It is remarkable that in ?7 cases the cause of the fracture was direct trauma.

19 patients also had associated injuries vertebral fractures in 4 and arm fractures in 4 and different types of fracture in the lower extremity in 11

Of the 110 fractures, 50 had been treated conservatively and 60 surgically (Table 1) Of the conservative group 42 were treated with immobilisation in plaster alone, while the remaining 8 had been treated by various (combined) methods.

Of the 60 fractures treated surgically arthrodesis had been done in as many as 54 *e* either between the talus and the calcaneus (subtaloid arthrodesis) or between the talus and calcaneus, calcaneus and cuboideum, talus and naviculare (triple

PRESENT MATERIAL

The material consisted of all fractures of the calcaneus treated at the Department of Orthopaedics University Hospital Lund between 1939 and 1961 Treatment was not uniform but more than half of the patients had been subjected to primary subtaloid arthrodesis or to triple arthrodesis.

The classification is according to *Widen* but with the following modification

Figure 1

Type A

Group I Fracture of the posterior superior part of the tuberosity





Group II Fracture of the medial tubercle



Group III Fracture of the sustentaculum



Group IV Fracture of the anterior process



Group V Extra articular fracture and intra-articular fracture without displacement of joint fragments

N° OF CASES

10

5

12–20 21–30 31–40 41–50 51–60 61–70 71–87

AGE IN YEARS

Figure 3 Age and distribution of female material
Filled columns = patients reviewed

occurred in the track of the transfixion pin The complications in the remaining 8 cases consisted in infection or skin necrosis All of the 8 had been operated upon within the first week of the injury

The interval between the injury and the review was 2–22 years. At the review notes were made of symptoms (pain feeling of stiffness weight bearing capacity walking capacity) performance (whether the patient could return to his usual work or whether he was obliged to choose a lighter occupation) and signs (muscle atrophy deformity limp swelling tenderness sensibility disorders stability of arthrodesis range of motion of talocrural joint) The review also included roentgen examination (Bohler angle, healing pseudarthrosis, osteitis deformans) The end results were classified as excellent good fair or poor according to the findings made at the review

Table 1

110 fractures of calc.
(94 patients)

Conservative					Operative			
50					60			
1	1	2	4	42	46	8	3	3
Untreated	Physiotherapy	According to Bohler	Calc traction	Plaster	Triple arthrodesis	Subtal. arthrodesis	Open reduction	Open reduction + screw

Excellent Relatively normal foot patient returned to original occupation within 6 months of the end of treatment and patients not considered entitled to diability pension fractured area or arthrodesis healed.

Good Very mild symptoms only on exertion or when walking on uneven ground or up or down steps Slight swelling slight tenderness to deep palpation Patient returned to work within 6 months no disability pension Fracture or arthrodesis healed.

Fair Moderate persistent symptoms walking on uneven ground painful. Resumed work but lighter occupation within 6 months of treatment Disability pension (10 to 15 per cent) Roentgen findings uncertain regarding healing of arthrodesis etc.

Poor Severe symptoms Deformity of foot. Still disabled 6 months after treatment change of occupation often necessary Disability pension 15 to 50 per cent Roentgen examination showed unhealed arthrodesis or sequelae after osteitis

RESULTS AND DISCUSSION

The results are given in Tables 2–4 Extra articular and intra articular fractures without dislocation offer no problems They need no treat ment or only immobilisation in plaster

50 fractures (32 type A and 18 type B) were treated conservatively

Table 2 Results of conservative treatment

	Excellent	Good	Fair	Poor	Total
Group I–V Fracture type A	14	15	1	2	32
Group VI–VII Fracture type B	1	3	1	13	18
Total					50

Table 3 Results of operative treatment

	Excellent	Good	Fair	Poor	Total
Group I–V Fracture type A	4	3			7
Group VI–VII Fracture type B	13	10	2	28	53
Total					60

(Table 2) Of the 32 cases belonging to type A and treated with plaster the results were excellent or good in 29 and fair or poor in 3 Of the 18 of type B the results were excellent or good in only 4 and fair or poor in 14

Of the 60 fractures (7 of type A and 53 of type B) treated surgically (Table 3) the end results were excellent or good in 30 and fair or poor in 30

Subtaloid arthrodesis was done in 8 cases (2 belonging to type A and 6 to type B) and triple arthrodesis in 46 (2 of type A and 44 of type B)

Of the 8 cases subjected to subtaloid arthrodesis the results were excellent or good in only 2 but fair or poor in all 6 cases of type B Of these 6 patients 5 had been operated upon within 4 days of the accident

Table 4 Results of operative treatment performed at various intervals after accident

Interval between accident and operation	Type of operation	Excellent–good	Fair poor
1–3 days	Triple arthrodesis	12	1
	Subtaloid arthrodesis	2	1
	Screw	2	
	Open reduction	2	
4–7 days	Triple arthrodesis	5	7
	Subtaloid arthrodesis		2
8–14 days	Triple arthrodesis	3	7
	Subtaloid arthrodesis		2
	Screw	1	
	Open reduction		1
15–21 days	Triple arthrodesis	1	2
21 days to 19 months	Triple arthrodesis	2	6
	Subtaloid arthrodesis		1
Total		30	30

In the 46 cases where triple arthrodesis had been performed the results were excellent or good in 23 and fair or poor in 23 Of the 23 cases with good results 12 had been operated upon 1–3 days after the injury 5 after 4–7 days 3 in the second week 1 in the third week and 2 still later (Table 4)

In those cases where the results were poor only 1 had been operated upon on the day of the accident while 7 had been operated upon 4-7 days after the injury 7 in the second week 2 in the third week and 6 still later

On classification of the results according to the interval between the injury and the operation it was found that of those in whom the operation was performed within 3 days of the accident the end results were excellent or good in 18 and fair or poor in 2

In a chapter on triple arthrodesis based on material from Prof Moberg s department in Gothenburg *Thoren* (1964) pointed out that in the evaluation of the results it should be borne in mind that the material was selected in that it contained several cases that were severe and had therefore been referred to that special hospital for treatment

During the period covered by the present investigation (1939-1961) the material consisted of cases from Malmohus county and from different hospitals in the south of Sweden

Of the 94 patients in the present material, only 58 were residents of the receiving area of the Lund Hospital Of the remaining 36 5 were of type A and 31 of type B This probably means that severe fractures were referred to us from other hospitals

The above mentioned results suggest either that early operation is preferable or that cases operated on after 4 days were severe cases with extensive injuries referred to our hospital from the peripheral region This is in accordance with Thoren s discussion above

SUMMARY

In 1939-1961 all together 123 patients were admitted to the Department of Orthopaedics because of fracture of the calcaneus Ninety four of these with 110 fractures (50 treated conservatively and 60 surgically) were reviewed

For the classification Widen s system was used but group V was incorporated in type A leaving only the most severe cases (group VI and VII) in group B

Conservative treatment Fifty fractures 32 of type A groups I-V i e extra articular or intra articular fracture without dislocation treated with plaster had produced good results in 29 and poor results in 3 while in 18 of type B i e intra articular fractures with dislocation and treated conservatively had given good results in 4 and poor results in 14 Fractures of type A can thus be successfully treated conservatively

Surgical treatment Sixty fractures (7 of type A and 53 of type B) were treated surgically Triple arthrodesis had been done in 46 with good results in 23 and poor results in 23 subtaloid arthrodesis in 8 with good results in 2 and poor results in 6 Three were treated with a screw all with good results and 3 with open reduction with good results in 2 and poor in 1

The results and the incidence of complications appeared to vary with the interval between the injury and arthrodesis An interval of 4–7 days between the accident and operation carries a risk of mediocre results The best results may be expected after early surgery

It is pointed out that 36 out of 94 patients were referred to the Orthopaedic Department in Lund from other hospitals in south Sweden and they represented fairly severe cases 31 of the 36 cases were of type B Like *Thoren* (1964) we suspect that this material of arthrodesis cases is selected This must be borne in mind when judging the value of triple arthrodesis in severe calcaneal fractures

REFERENCES

1 Ahlberg A (1940) *Studien über 111 nachuntersuchte Fälle von Calcaneus frakturen* Goteborg

2 Armstrong J R (1943) Posterior subastragaloid arthrodesis in fractured os calcis *Lancet* 245 506

3 Arnesen A (1939) Extensionsbehandlung der Calcaneusfraktur *Acta Chirurg* 11 115

– (1958) Fractures of the os calcis and its treatment. *Acta chir scand* Suppl 234

4 Ashhurst A (1921) Malunion of the calcaneus from crushing fracture Bone transplantation *Ann Surg* 74 108

5 Astrup A (1952) Fracture processus anterior lateralis calcanei. *Ugeskr f Læger* 114 910

6 Bankart, B (1942) Fractures of the os calcis. *Lancet* 2 175

7 Bartley S P (1931) Treatment of fractures of the body of the os calcis. *Surg Clin North Amer*

8 Becker F (1951) Primare Arthrodese bei der Behandlung von Fersenbrüchen *Zentralblaat Chir* 76 834

9 Beesly L. & Price E. (1914) Avulsion fracture of the os calcis. *Edinburgh M J* 12 436

10 Brattstrom H (1953) Primar arthrodes vid grav calcaneusfraktur *Nord Med* 50 1510

11 Breithaupt (1855) Zur Pathologie des menschlichen Fusses. *Med cin Zeitung* 24 169–171 175–177

12 Bohler (1928–9) Behandlung der Fersenbeinbruches. *Chirurg* 1 733 The treatment of fractures. 4th edition 1935 Translated by Ernst W Hey Groves.

13 Campbell W G (1941) Simple operation for reduction of fractures of the os calcis. *Brit M J* 2 651–652

15 Cherry J E (1946) Fractures of the os calcis *Irish J M Sc* 6 1?? (1947) Avulsion fracture of the os calcis *Irish J M Sci* 6 3?

16 Clemınson K (1953) Excision of calcaneum for fracture. *J Bone Jt Surg* 34 B 158

17 Colonna P (1950) *Regional orthopedic Surgery Textbook* p 479–481

18 Conn, H R. (1935) The treatment of fractures of the os calcis *J Bone Jt Surg* 17 592

19 Cotton F J (1921) Old os calcis fractures *Ann Surg* 74 294

20 Dachtler H W (1931) Fractures of the anterior superior portion of the os calcis due to indirect violence *Amer J Roentgenol* 25 629

21 Danis R (1951) Cit by *Belenger Vandler elet & lorthoıd*

22 Day F Gm (1950) Treatment of fractures of os calcis *Canad M J* 63 373 376

23 Dell, J M (1958) Of ant. sup process need for correct diagnos & adequate ther to prevent permanent disability *Southern Medical Journal* (Birmingham Acad) P 1161–1164

24 Destot E (1902) Fractures du tarse postérieur *Rev de Chir* (Paris) 26 ?18.

25 Dick I L (1953) Primary fusion of posterior subtalar joint in treatment of fractures of the calcaneum *J Bone Jt Surg* 35 A 375–380

26 Eiken Th. (1917) *De traumatiske frakturer af forfodens knogler* Copenhagen.

27 Eisendrath D N (1905) Fractures of the tarsal bones *Ann Surg* 41 363

28 Essex Lopreeti P (1951) Results of reduction in fractures of the calcaneum. *J Bone Jt Surg* 33 B 284 – (1952) The mechanism reduction technique and results in fractures of the os calcis *Brit J Surg* 39 395

29 Estwood W J (1938) Whose review of 47 cases *Brit J Surg* 25 636

30 Garengeot R J (1731) *Traité des opérations* Ed 2 Paris

31 Gelinsky E (1913) Die Eextensionsbehandlung bei Calcaneusfraktur und den Verletzungen der Mittelfussknochen *Zentralbl Chir* 40 809

32 Gellman (1951) Fractures of the ant. process of the calc *J Bone Jt Surg* 33 A 382

33 Gill G G (1944) A three pin method for treatment of severely comminuted fractures of os calcis *Surg Gyn & Obst* 78 653–656

34 Gollasch W (1941) Behandlungsergebnisse von 250 Fersenbeinbrüchen *Hefte ur Unfallheilkunde* 31 1 – (1952–53) Zur Behandlung des frischen Fersenbeinbruches *Arch f Klin Chir* 273 792

34a Graham Aply (1959) Textbook.

35 *Grays Anatomy Descriptive and Applied* (1950) Pp 422–424

36 Grant (1958) *A method of anatomy*

37 Hall McPennal G F (1960) Primary subtalar arthrodesis in the treatment of severe fractures of the calcaneum *J Bone Jt Surg* 42 B 336–343

38 Harris R L (1944) Improved methods of treatment. *Bull Vancouver M A* 21 43–47 – (1946) Fractures of the os calcis *Ann Surg* 124 108? – (1963) Fractures of the os calcis Treatment by early subtalar arthrodesis *Clin Orthoped* 30 100

39 Hauser E. (1945) Managements of lesions of the subtalar joint *S Clin North America* 25 136

40 Hosford J P (1936) Prognosis in fractures of the os calcis *Lancet* 230 ?33

41 Hullinger C W (1944) Insufficiency fracture of the calcaneus similar to march fracture of the metatarsals *J Bone Jt Surg* 26 551–57

42 Holund T (1951) Fracture calcanei behandlet a. m. Arnesen. *Nord Med* 45, 884.

43 Jaekle, R. F & Clark, A G (1937) Fractures of the os calcis. *Surg Gyn & Obst* 64 663–672

44 Juvara E (1911) Fracture par arrachement de la tuberceite du calcaneum. *Presse Medicale* 19 689

45 Kiaer S & Anthonsen W (1942) Fracture of the calcaneus treated with arthrodesis. *Acta chir scand* 87 191–213

46 Lang K (1939) Rissfraktur des calcaneus *Zentralbl Chir* 66 1599

47 Lauritzen G (1947) Behandling av calcaneusfrakturer enligt Westhues. *Nord Med* 36 2025–2027

48 Leabhart, J W (1959) Stress fractures of the calc *J Bone Jt Surg* 41 A 1295

49 Lenormant, C Wilmoth P & Lecoeur A. (1938) A propos du traitement sanglant des fractures du calcaéum *Bull et mém. Soc Nat de Chir* 54, 1353

50 Leriche R. (1913) Fracture complique du calcanéum. Résection immediate. *Lyon Med* 120 1185 – (1922) Osteosynthése primitive pour fracture par écrasement du calcaneum *Lyon Chir* 19 559

51 MacAusland W R. (1941) Treatment of comminuted fract. *Surg Gyn & Obst* 73 671–675

52 MacBride, E. D (1944) Tripod pin traction apparatus. *J Bone Jt Surg* 26, 578–579

53 Mandruzzato F A (1951) Sur le traitement des fractures du calcaneum. *Acta Ortop Belgica* 17 220

54 Moberg E & Erfors C G (1953) Primar therapi vid grava intraartikulara calcaneusfrakturer *Nord Med* 49 150

55 Monod R C (1930) Traitement des fractures par écrasement du calcaneum par la double arthrodése medio tarsienne et sousastragalienne. *Bull et mem Nat de Chir* 56 1159

56 Mooney V (1935) Avulsion of the epiphysis of the os calcis *J Bone Jt Surg* 17 1056

57 Mourgues a de Mourgues (1960) Treatment of fractures of the calcaneum—place of reconstruction arthrodesis. *Rev chir* 46 710–720

58 Nissen Lie H. S (1946) After examination of 32 conservatively treated fractures. *Nord Med (Norsk Mag f Lægevidensk.)* 29 1295–1297

59 Norman R. (1947) Symposium on fracture of the os calcis. *J Bone Jt Surg* 29 254.

60 Nové-Josserand (1928) Sur un cas de reduction sanglante primitive d une fracture du calcanéum par écrasement. *Lyon Chir* 25 217

61 O shea M C (1944) With dislocation of subastragaloid joint. Two cases one of which was compound. *New York State J Med* 44 49–55

62 Palmer L (1945) Forslag till operativ behandling av vissa kalkaneus frakturer *Nord Med* 26 869 – (1948) The Mechanism and treatment—open reduction with use of cancellous grafts. *J Bone Jt Surg* 30 A 2–8

63 Paitre, F & Boppe M (1935) *Les fractures du calcaneum.* Congress Francais de Chir P 371

64 Platt A (1956) Fractures of the promotory of the calc. *Radiology* 67 386.

65 Pride K H (1946) New method of treatment for severe fractures preliminary report *Surg Gyn & Obst* 82 671-675
66 Raisman J (1944) Spontaneous fracture *Amer J Surgery* 65 290-292
67 Sallick, M A & Blum L (1948) Sensory denervation of the heel for persistent pain following fractures of the calcaneus *J Bone Jt Surg* 30 A 209
68 Scheller (1939) Uberbelastungsschaden am knochengerust junger Manner *Med Welt* 13 1333-1336
69 Schofield R.C. (1936) Fractures of the os calcis. *J Bone Jt Surg* 18, 566
70 Schoolfield B L (1944) Newer method in treatment *Texas State J Med* 40 294-297
71 Scudder E.L. (1938) *The treatment of fractures* Textbook, Philadelphia and London
72 Simon R & Stulz E (1928) Traitement sanglant des fractures par ecrasement du calcanéum. *Bull et mem Soc Nat de Chir* 54 1293
73 Sobotta Becher (1957) *Atlas der descriptiven Anatomie des Menschen* P 176
74 Soubeyran P & Rives A (1913) Fractures du calcanéum *Rev de Chir* (Paris) 43 429
75 Stewart J E (1934) *South M J* 27 711
76 Struppler V (1937) Abrissbruch am Fersenbein *Brun s Beitr Klin Chir* 166, 402 — (1939) Fissbruch am Fersenbeinhocker *Arch orthop U Unfall Chir* 39 651
77 Stulz etal (1951) Réflexions sur ledtraitement des fractures du calcaneum d après 61 observation *Acta Ortop Belgica* 17 231
78 Tavernier L & Godinot C H (1945) *Traitement chirurgical de l arthrite sèche de la hanche* Paris
79 Thompson K & Friesen C M (1959) Treatment of comminuted fractures of the calcaneus by primary arthrodesis *J Bone Jt Surg* 41 A 1423 1436
80 *Thorén O (1964) Os calcis fractures*
81 Van de Mark, R. E. & MacCarthy P V (1946) March fracture. *Radiology* 46, 496-501
82 Van Stockum (1912) Operative Behandlung der Calcaneus und Talusfraktur *Zentralbl Chir* 39 1438
83 Watson-Jones R. (1960) *Fractures and joint injuries* Textbook P 867 868
84 Westhues H (1934) Zur Behandlung der Calcaneusfraktur *Zentralbl Chir* 61 2231 — (1944) Eine neue Behandlungsmethode der Calcaneusfraktur *Arch. Orthop U Unfall Chir* 35 121 — (1942) Uber Fersenbeinbruche *Zentralbl Chir* 69 714
85 Widén A (1954) Fractures of the calcaneus *Acta chir scand* Suppl 188
86 Wilmouth P & Lecoeur P (1929) Le traitement operatoires des fractures sous thalamiques des calcanéum *J de Chir* 33 781
87 Wilson P D (1927) Treatment of fractures of the os calcis by arthrodesis of the subastragalar joint *J A.M.A* 89 1676
88 Verschutz J (1936) Zur behandlung der Calcaneus Brüche *Zentralbl Chir* 63 610
89 Yoerg O W (1937) *Surg* 2 493

Acta orthop Scandinav 40 543–551 1969

Department of Engineering University of Waterloo Toronto Western Hospital and Department of Surgery University of Toronto and Small Animal Section Ontario Veterinary College, University of Guelph Ontario Canada.

THE EFFECT OF DELAYED INTERNAL FIXATION ON FRACTURE HEALING

An Experimental Study

K Piekarski A M Wiley & J F Bartels

Received 26 ix 68

In the application of internal fixation to certain closed fractures the rationale for early surgery has long been accepted (Murray 1941) and the proper use of improved internal fixative devices particularly those employing compression or rigid intramedullary nails may result in a rapid return of function and very low rates of non union Nevertheless there is now abundant clinical evidence that delayed internal fixation performed after a waiting period produces a significant drop in the overall incidence of non union This conclusion is based on the operative results of different surgeons working with differing fixative devices (Charnley 1961 Emery 1965 Lam 1964 Smith 1959 1964 Borden & Smith 1962)

The waiting period constitutes a time interval of one to three weeks after fracture though some reports indicate a period longer than this

Published material allows no such conclusions in the case of compound fractures Furthermore there is clinical evidence that in the case of femoral shaft fractures delayed internal fixation may be followed by an increase in callus formation (Charnley & Guindy 1961)

The discovery that closed fractures heal more readily if operated upon late rather than early must mean that after a delayed period healing is rendered more efficient This can only be due to effective callus itself the result of local or possibly remote factors Some consideration must also be given to variations in operative technique for example although procedures for internal fixation may often be more effective as a formal operation than as an emergency measure the broad scope of the clinical series does not support the



Figure 1 Instron testing machine.

mechanical factor as being of major importance (Lam 1964). It is the possibility of a 'second injury' (Stager & Smith 1959) phenomenon in callus that prompted this experimental investigation.

MATERIALS

Rabbits were used in the experiment, the stock being Belgian Whites. All were grown but not fully mature. A standard diet of purina rabbit kibble was provided.

Closed fracturing of a limb introduces so many variables that it was decided to section the radius surgically under general anaesthetic. This was achieved by inserting a nasal septum saw through a small skin incision which was then sutured. (In experimental animals there is no evidence that a delay in fracture-healing results from such operative exposure (Herms & Blount 1964).)

Maximum sterile precautions were maintained, the skin in each leg being shaved and bared by a chemical epilator before being painted with surface antiseptic.

In this way a fracture was produced at a similar site in each animal. Splinting

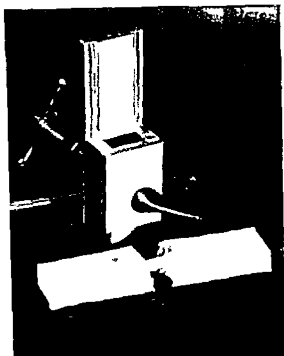


Figure 2 Aluminium mould and a radius mounted in acrylic resin

was not required for the rabbit radius which is very tightly bound to the ulna by the interosseus membrane

Exclusive of animals used in a preliminary pilot project, there were available two hundred and ten rabbits providing approximately twice this number of specimens although some were un united, comminuted or infected and thus rejected.

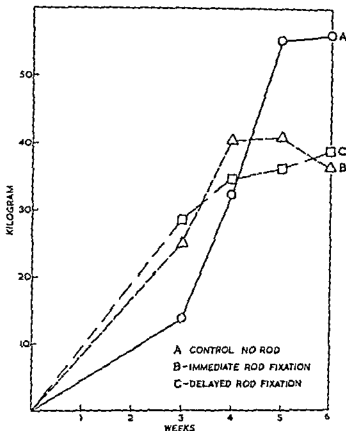
PREPARATION OF SPECIMENS

In each animal after sacrifice the radius was removed and dissected free of soft tissues. Initially the specimen was immersed in formalin A pilot study performed on fractures prepared in this fashion indicated that formalin rendered specimens brittle a factor previously noted by other workers (McElhaney Fogel Byars & Weaver 1964) Subsequently each specimen was wrapped in cellophane and placed in the deep freeze compartment of a domestic refrigerator

Designation of Tests

Group A These consisted of fractures surgically produced as described and designated A specimens. (No intramedullary fixation applied) These rabbits were sacrified three four five, and six weeks after fracturing.

Group B These were obtained three four five and six weeks after fracturing



Graph 1 Fracture strength

where an intramedullary K wire has been introduced through the wound at the time of wounding This was immediate intramedullary fixation (B specimens)

Group C These were obtained by sacrificing animals at the same time periods as Group B In these the intramedullary K wire was introduced *a week after* the fracture by re opening and re suturing the wound (*C* specimens)

Testing Procedures

The strength of callus was tested in tension as by Falkenberg (1961) The work was performed on an Instron testing machine (Figure 1) The ends of each un frozen bone were mounted in acrylic resin using an aluminium mould (Figure 2) The radius mounted in this manner was inserted between the jaws of the Instron tester and pulled in tension

The maximum loads at which fracture of the callus occurred are shown in Graph 1

The two fragments of each specimen were retained One was preserved in for malin for future histological examination and one served for computation of the cross sectional area of the callus at the fracture site and of its porosity To assure

the best possible accuracy the fractured end of a callus was polished flat and a photomicrograph was made with the aid of a standard metallurgical microscope. From the photomicrograph the porosity of the callus was estimated and its cross section measured with a planimeter. The results are shown in Graph 2 and Graph 4. Finally the total volume of callus in each specimen was calculated by approximating its shape to that of an ellipsoid, Graph 3.

RESULTS

Fracture Strength

Graph 1 shows that the radii from the group of animals having no intramedullary nail attained the greatest strength five and six weeks after fracturing (Group A). The statistical level of significance of difference between this group and C specimens (rod inserted one week after fracture) was 0.30.*

The fracture strength for B and C groups increased in approximately the same manner.

Fracture Cross sectional Area and Callus Volume

Graph 2 indicates that in the initial stages of healing (up to 3 weeks) Group C has developed a greater cross sectional area than the other groups. The calculated level of significance of difference between Group C and Group A was 0.25.

Graph 3 supports this evidence and shows a much greater volume of callus at the same period. The level of significance of difference between Group C and Group B was 0.001. A surprisingly high value was attained in three weeks by the control Group A.

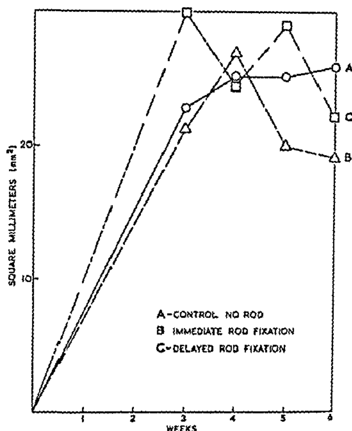
In both graphs the large initial cross-sectional area and volume tapered off to about the same value after a period of 5 to 6 weeks.

Porosity of Callus

Graph 4 partly justifies the values indicated on the previous graphs at the critical period of three weeks. The low strength of the callus having a large cross section may be explained by the greater porosity at this period. Again the greatest porosity is displayed by Group C.

---

* The level of significance is calculated from the "t" test for the estimated standard error of the difference between two sample means. It signifies that there is 0 per cent probability that the value for Group A is higher than the value for Group C.



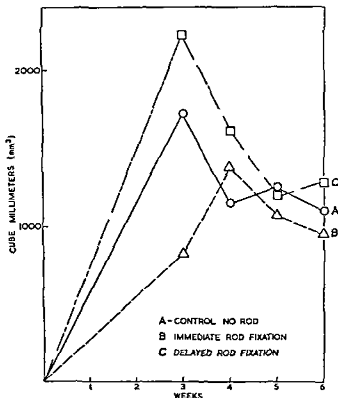
Graph 2 Callus cross sectional area at the fracture site

The level of significance of difference between Group C and Group A was also 0·001 The rapid decrease in porosity in later weeks indicates a vigorous rate of remodelling of callus

COMMENT

It was not the purpose of this study to investigate the factors responsible for callus changes in fractures treated by delayed internal fixation rather it has been an attempt to illustrate that such changes do in fact occur In the clinical series describing the phenomenon there is speculation about the existence of general and local hormonal factors in operation The response of a fracture twice disturbed resembles that of a wound resutured after a waiting period

Local mechanical factors undoubtedly influence the process but we find it hard to believe that an immediate operative internal fixation



Graph 3 Total volume of callus

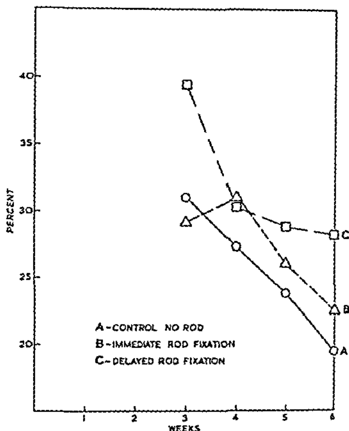
creates more tissue damage than a delayed procedure Possibly the periosteum and soft tissues strip more widely in the immediate operation

The experimental material so far presented has supported the clinical observation that callus forms rapidly and in increasing bulk following a delayed surgical internal fixation where this is necessary Prior wounding failed to result in stimulated callus The indications are that delayed intervention has a local stimulatory effect on the normal reparative process

Further work is *in progress in an attempt to clarify this issue*

SUMMARY

The *findings in these animal experiments indicate a stimulation of* callus production in fractures treated by delayed internal fixation



Graph 4 Porosity of callus

This effect is at its maximum after the insertion of the fixative device Thereafter the callus becomes remodelled in a similar fashion to the callus forming after immediate open reduction

In the critical healing periods such delayed surgery does not appear to confer any increased callus strength when specimens are tested in tension

ACKNOWLEDGMENTS

This work was financed by a grant from the Rehabilitation Foundation for the Disabled supplemented by funds donated by the Toronto Western Hospital.

The authors wish to express their gratitude for advice and guidance on the use of experimental animals to Dr A J Cawley Head of the Small Animals Department Veterinary College University of Guelph

The research project was performed at the University of Waterloo using their equipment and facilities Help in testing was contributed by Mr P Guest and Mr J Hackl students of the University

A pilot study was performed by Dr A J Phares lately of the Toronto Western Hospital and now at Beirut, Lebanon

REFERENCES

Borden, J N & Smith W S (1952) Refracture of the shaft of the femur *Southern med J* 874

Charnley J & Guindy A (1961) Delayed operation in the open reduction of fractures of long bones *J Bone Jt Surg* 43-B 4 664

Emery M A (1965) The incidence of delayed union and non union following fractures of both bones of the forearm in adults *Canad J Surg* 8 3

Falkenberg J (1961) An experimental study of the rate of fracture healing *Acta orthop scand* Suppl 50

Ham A W (1957) *Histology* 3rd ed. Lippincott & Co New York

Herms, R A & Blount W P (1964) Effect of open reduction upon fracture healing *Surg Forum* 15 448

James, W V (1964) The time factor in the operative treatment of fractures of the long bones *J int Coll Surg* 41 5 515

Lam S J (1964) The place of delayed internal fixation in the treatment of fractures of the long bones *J Bone Jt Surg* 46-B 1 122

McElhaney J., Fogle J., Byars E & Weaver G (1964) Effect of embalming on the mechanical properties of beef bone *J appl Physiol* 19 6 1234

Murray C M (1941) The timing of the fracture healing process *J Bone Jt Surg* 23 3 598

Smith, J E M (1959) Internal fixation in the treatment of fractures of the shafts of the radius and ulna in adults *J Bone Jt Surg* 41 B 1 122

Smith J E M (1964) The results of early and delayed internal fixation of fractures of the shaft of the femur *J Bone Jt Surg* 46-B 1 28

Stager R F & Smith W S (1959) The second injury phenomenon as it relates to fractures *Surg Forum* 10 826

Acta orthop Scandinav 40, 552–562 1969

Department of Orthopaedic Surgery (Head A Hulth) Malmö General Hospital
University of Lund Malmö Sweden

EXPERIMENTAL LIMB DISUSE AND BONE BLOOD FLOW

HELGE SEMB

Received x 68

It is known that blood vessels in immobilized limbs are prone to undergo anatomic changes (*Braibanti* 1958 *Geiser & Trueta* 1958 *Hulth & Olerud* 1960 1961 *Jaffe* 1930 *Landoff* 1942 *Rieder* 1936 *Semb* 1966, *de Valderrama & Little* 1965) Thus immobilization of a limb for one to two weeks is sufficient to produce dilatation and tortuosity of arteries veins, and capillaries in its soft tissues and of capillaries and sinusoids in the bone marrow and bone tissue

A few haemodynamic studies have been carried out on animal limbs immobilized in plaster Using electromagnetic flow meters *Imig et al* (1953) found two weeks immobilization of the hindleg of the dog in plaster to increase the blood flow in the limb by about 25 per cent Shim (1966) used the initial clearance of ^{85}Sr by the bone tissue as a measure of its capillary circulation in an investigation of rabbit and dog limbs immobilized in plaster He found the capillary blood flow through the bone tissue to be decreased after one to two weeks but to be increased by 50 per cent after two months

The purpose of the present investigation was threefold namely to study the circulation in bone tissue during the initial period of immobilization to follow the effect of continued immobilization on the bone blood flow and to study any correlation between that flow and the development of disuse osteoporosis

MATERIAL AND METHODS

One hundred and nine rabbits of mixed breed and sex were used The animals weighed between 2.0 and 3.0 kg In 34 of the animals the left hind leg was immobilized in plaster for periods of two hours to seven weeks

The rabbits were then assigned to different groups used in the following studies (1) acid base balance in the arterial blood and in bone marrow blood from the

right and left tibia (49 treated and 15 untreated controls) (2) oxygen saturation of arterial blood and of bone marrow blood from the right and left tibia (23 animals) (3) blood flow through the right and left tibia and calcaneus (2? animals)

One foreleg in each of six adult dogs of mixed race and sex was immobilized in plaster with the elbow in semiflexion and the radiocarpal joint in 90 volar flexion. The animals were immobilized for 2 14 and 28 days, respectively after which the blood flow through the distal part of the radius was studied in both forelegs

Acid base balance in arterial and bone marrow blood Small blood samples were obtained from an artery and bilaterally from the tibial bone marrow cavities of anaesthetized rabbit as described previously (Semb 1966a)

The acid base status in the blood samples was promptly determined with the micromethod and apparatus (Radiometer Copenhagen) described by Siggaard Andersen et al (1960) In the present investigation pH was measured with equal accuracy as reported by Siggaard Andersen et al (1960) In a control group of 15 rabbits the acid base status was measured in bone marrow blood from the right tibia and from the left. No significant differences were found between the samples from the two sides

The hind legs of the animals were examined roentgenographically In addition, transverse sections were cut at corresponding levels from both distal tibial metaphyses. The slices were manually ground down to a thickness of one hundred microns and examined microradiographically

Oxygen saturation of arterial and bone marrow blood The influence of plaster immobilization on the blood oxygen saturation was studied in small blood samples from an artery and from the bone marrow of both tibial bones (Semb 1966b) The oxygen saturation (HbO_2) was measured spectrophotometrically (Siggaard Andersen et al 1962) with a slight modification. The accuracy of the method was studied on blood from capillary tubes filled with heparinized blood from one and the same sample. S D was ± 2 2 and the S E. ± 0 6 per cent saturation

Bone blood flow The initial clearance of intravenously administered ^{85}Sr was used as a measure of the blood flow through the bone tissue.

In the rabbits the capillary bone blood flow was estimated in relative terms in immobilized and contralateral, untreated *legs as described in an earlier paper* (Semb 1968) In this study bone marrow blood from the tibial bones was assumed to be predominantly venous Principally the same technique was used in a study on the effect of immobilization on the bone blood flow through the distal metaphysis of both radial bones of dogs In this investigation however the total bone blood flow was estimated quantitatively according to Fick s principle (Semb 1966c)

RESULTS

Four of the rabbits in group 1 (acid base balance) were excluded owing to technical mishaps in association with analysis of the blood samples Analyses of blood from the other animals gave results suggesting certain systematic changes

Figure 1 gives the differences between the pH values in the blood from immobilized and from normal bone after various periods of

was significant ($P < 0.001$) but there was no connection between changes in *HbO* and immobilization time (correlation coefficient 0.259). The average oxygen saturation in the arterial blood was 88.2 (S.D. ± 12.1, S.E. ± 2.5), in marrow blood from the immobilized leg 79.5 (S.D. ± 10.4, S.E. ± 2.2) and from the control leg 71.[illegible] (S.D. ± 10.0, S.E. ± 2.1) per cent.

The uptake of ^{85}Sr by bone tissue, an indicator of the capillary blood flow, was distinctly affected by the treatment and varied with the duration of the immobilization.

Figure 4 gives the average difference in uptake between the treated and untreated side of rabbits after different periods. In the very early stage (after 2 hours) the uptake of ^{85}Sr decreased considerably. The differences were then significant for the different parts of the bone ($P < 0.001$). The uptake, however, soon became normal again. Already after one day the values for the uptake on the treated side were almost the same as on the untreated. The uptake by the bone tissue on the immobilized side then increased successively. The transition to an increase occurred some time between the first and seventh

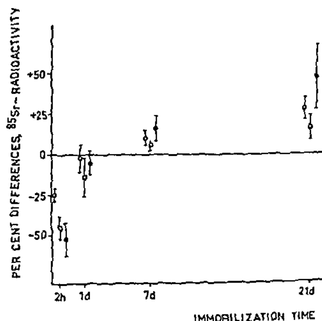


Figure 4. Differences (in per cent) between ^{85}Sr radioactivity in bone of different sources from immobilized and control legs as a function of time. Standard error of the mean. Bone sources: (○) proximal tibia, (□) distal tibia, (●) calcaneus.

right and left tibia (49 treated and 15 untreated controls) (2) oxygen saturation of arterial blood and of bone marrow blood from the right and left tibia (23 animals) (3) blood flow through the right and left tibia and calcaneus (22 animals)

One foreleg in each of six adult dogs of mixed race and sex was immobilized in plaster with the elbow in semiflexion and the radiocarpal joint in 90° volar flexion. The animals were immobilized for 2, 14 and 28 days respectively after which the blood flow through the distal part of the radius was studied in both forelegs.

Acid base balance in arterial and bone marrow blood Small blood samples were obtained from an artery and bilaterally from the tibial bone marrow cavities of anaesthetized rabbit as described previously (Semb 1966a)

The acid base status in the blood samples was promptly determined with the micromethod and apparatus (Radiometer Copenhagen) described by Siggaard-Andersen et al. (1960) In the present investigation pH was measured with equal accuracy as reported by Siggaard Andersen et al (1960) In a control group of 14 rabbits the acid base status was measured in bone marrow blood from the right tibia and from the left. No significant differences were found between the samples from the two sides

The hind legs of the animals were examined roentgenographically In addition transverse sections were cut at corresponding levels from both distal tibial metaphyses. The slices were manually ground down to a thickness of one hundred microns and examined microradiographically

Oxygen saturation of arterial and bone marrow blood The influence of plaster immobilization on the blood oxygen saturation was studied in small blood samples from an artery and from the bone marrow of both tibial bones (Semb 1968b) The oxygen saturation (HbO_2) was measured spectrophotometrically (Siggaard Andersen et al. 1962) with a slight modification The accuracy of the method was studied on blood from capillary tubes filled with heparinized blood from one and the same sample. S D was ± 2.2 and the S E. ± 0.6 per cent saturation

Bone blood flow The initial clearance of intravenously administered ^{85}Sr was used as a measure of the blood flow through the bone tissue

In the rabbits the capillary bone blood flow was estimated in relative terms in immobilized and contralateral untreated legs as described in an earlier paper (Semb 1968) In this study bone marrow blood from the tibial bones was assumed to be predominantly venous. Principally the same technique was used in a study on the effect of immobilization on the bone blood flow through the distal metaphysis of both radial bones of dogs In this investigation however the total flow blood flow was estimated quantitatively according to Fick's principle (Semb 1968c)

RESULTS

Four of the rabbits in group 1 (acid base balance) were excluded owing to technical mishaps in association with analysis of the blood samples Analyses of blood from the other animals gave results suggesting certain systematic changes

Figure 1 gives the differences between the pH values in the blood from immobilized and from normal bone after various periods of

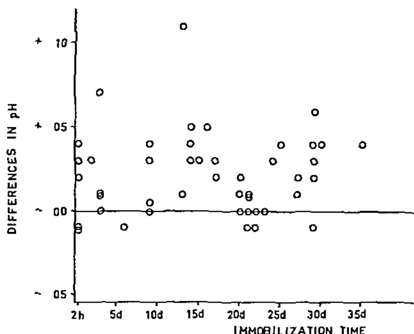


Figure 1 pH changes in intramedullary blood from legs immobilized for various periods

immobilization Irrespective of the duration of treatment the pH was somewhat higher on the treated side On the average the pH was 0 022 units higher on this side The difference was statistically significant ($P < 0\ 001$)

In arterial blood the average pH was 7 37 (S D ± 0 042 S L ± 0 007) The corresponding values for bone marrow blood from the immobilized and untreated side were 7 36 (S D ± 0 062 S L ± 0 009) and 7 34 (S D ± 0 062 S L ± 0 009) respectively

Figure 2 gives the relative differences between P_{CO_2} in marrow blood from the treated and from the untreated limb The values were constantly lower on the immobilized side The difference was statistically significant ($P < 0\ 001$) The correlation coefficient was 0 138 suggesting no connection with immobilization time The mean P_{CO_2} was 40 7 (S D ± 10 8 S E ± 1 9) and 43 8 (S D ± 12 1 S L ± 2 1) mm Hg in bone marrow blood from the treated and untreated side respectively

The standard bicarbonate level in the marrow blood in one leg did not differ significantly from that in the other The mean values were

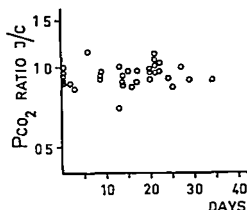


Figure 2 Ratios (in a logarithmic scale) between P_{CO_2} in intramedullary blood from legs immobilized for various periods and from control legs

22 0 (S D ± 3 1 S E ± 0 5) and 21 8 (S D ± 3 1 S E ± 0 5) mE/l in blood from immobilized and normal leg respectively

Figure 3 gives the relative differences in oxygen saturation between bone marrow blood from the treated and untreated tibia in relation to the duration of immobilization For all periods of immobilization the oxygen saturation was higher in blood from the immobilized side The average difference in saturation was 8 2 per cent The difference

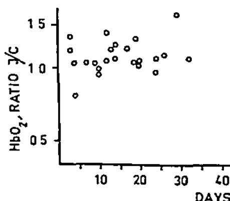


Figure 3 Ratios (in a logarithmic scale) between HbO_2 in intramedullary blood from legs immobilized for various periods and from control legs

was significant ($P < 0.001$) but there was no connection between changes in HbO and immobilization time (correlation coefficient 0.259). The average oxygen saturation in the arterial blood was 88.2 (S.D. ± 12.1, S.E. ± 2.5), in marrow blood from the immobilized leg 79.5 (S.D. ± 10.4, S.E. ± 2.2) and from the control leg 71.5 (S.D. ± 10.0, S.E. ± 2.1) per cent.

The uptake of ^{85}Sr by bone tissue, an indicator of the capillary blood flow, was distinctly affected by the treatment and varied with the duration of the immobilization.

Figure 4 gives the average difference in uptake between the treated and untreated side of rabbits after different periods. In the very early stage (after 2 hours) the uptake of ^{85}Sr decreased considerably. The differences were then significant for the different parts of the bone ($P < 0.001$). The uptake, however, soon became normal again. Already after one day the values for the uptake on the treated side were almost the same as on the untreated. The uptake by the bone tissue on the immobilized side then increased successively. The transition to an increase occurred some time between the first and seventh

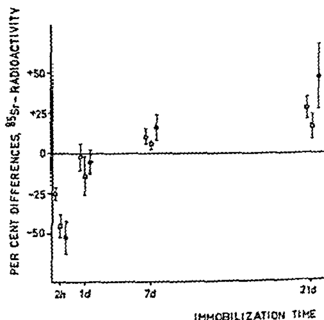


Figure 4. Differences (in per cent) between ^{85}Sr radioactivity in bone of different sources from immobilized and control legs as a function of time. Standard error of the mean. Bone sources: (○) proximal tibia, (□) distal tibia, (●) calcaneus.

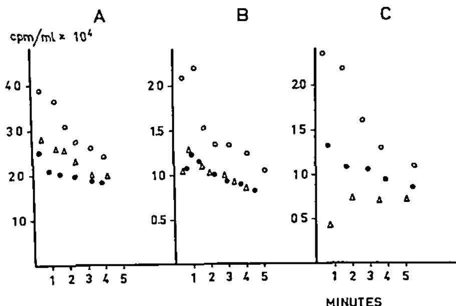


Figure 5 ^{85}Sr *radioactivity in arterial blood (○) and in bone marrow blood from immobilized (●) and control (Δ) legs during the period of measurement Periods of immobilization 2 hours (A) 7 days (B) and 21 days (C)*

day After 21 days the uptake was distinctly increased The difference was however significant only for the proximal part of the tibia ($P < 0.05$) The effect of immobilization on the uptake of ^{85}Sr appears to be strongest in the calcaneus (Figure 4)

The average extraction by bone of ^{85}Sr from perfusing blood was increased initially but decreased after 21 days on the immobilized side (Figure 5) This means that the decrease of bone blood flow after two hours indicated by the decreased uptake of ^{85}Sr in bone should be still more accentuated After 21 days however the blood flow should be still more increased than was shown by the uptake data

In the dogs the total blood flow through the distal radial metaphysis after 4 weeks was 50 per cent higher on the immobilized side After two and fourteen days respectively no disturbance in the circulation could be demonstrated The blood flow was estimated at about 25 millilitres/min/100 gram bone tissue on the untreated side

After 10 days immobilization X ray showed signs of atrophy of the tibia and calcaneus the corticalis was thinner and the spongiosa in

historadiographic investigation of bone specimens from *inter alia* immobilized rabbit limbs

Sunden (1967) paralysed the muscles of one hind leg of rabbits by division of the motor nerve roots He measured the heat clearance in the proximal tibial epiphysis and used this as a qualitative measure of the local blood flow Already after one day he found the blood flow on the treated side to be increased The increase was largest after six days Immobilization in plaster and division of the motor nerve roots of a limb thus appear to influence the bone blood flow in principally the same way Both measures result in muscular inactivity It is therefore possible that the precipitating factor is in activation of the musculature as pointed out previously by *inter alias*, *Whedon* (1960)

SUMMARY

The effect of immobilization of the limbs on the bone blood flow was studied experimentally in rabbits and dogs One limb served as a control After various periods of immobilization bone marrow blood from the limbs was examined regarding its acid base balance and oxygen saturation In addition the relative changes in the bone marrow blood flow were measured indirectly as the initial uptake of intravenously injected ^{85}Sr by bone tissue with correction for variations in extractions of the isotope from perfusing plasma

Irrespective of the type of treatment the pH and the oxygen saturation were increased and the carbon dioxide tension was decreased in the bone marrow blood from the immobilized limb Initially the bone blood flow was decreased but became normal again during the first week and then increased

The underlying mechanism of the increase in the bone blood flow is obscure It may be due to an increased collateral return of blood via vessels in the bone marrow and bone tissue as a compensation for the loss of the "muscle pump" Bone resorption does not appear to be favoured by impaired bone blood flow due to stasis On the contrary resorption appears to increase with the blood flow through the bone

REFERENCES

Bohatirchuk, F (19 6) Calciolysis as the initial stage of bone resorption. A stain historadiographic study Amer J Med 41 836 846

Braibanti T (1958) Die Arteriographie der Extremitaten bei den Folgen der Heine Medinschen Krankheit *Fortschr Rontgenstr* 89 274–280

Burkhart J M & Jowsey J (1967) Parathyroid and thyroid hormones in the development of immobilization osteoporosis *Endocrinology* 81 1053–1062

Cuthbertson E M Siris E & Gilfillan R S (1965) The femoral diaphyseal medullary venous system as a venous collateral channel in the dog *J Bone Jt Surg* 47 A 965–974

Geiser M & Trueta J (1958) Muscle action bone rarefaction and bone formation *J Bone Jt Surg* 40 B 282–311

Goldhaber P (1963) Some chemical factors influencing bone resorption in tissue culture In Sognnaes R F (ed.) *Mechanisms of hard tissue destruction* Amer Ass Adv Sci Washington D C pp 609–636

Goldhaber P (1965) Bone resorption factors cofactors and giant vacuole osteoclasts in tissue culture In Gaillard P J et al (eds) *The parathyroid glands Ultrastructure secretion and function* Univ Chicago pp 153–171

Hulth A & Olerud S (1960) Disuse of extremities I An arteriographic study in the rabbit *Acta chir scand* 120 220–226

Hulth A & Olerud S (1961) Disuse of extremities II A microangiographic study in the rabbit *Acta chir scand* 120 388–394

Imig C J Randall B F & Hines H M (1953) Effect of immobilization on muscular atrophy and blood flow *Arch phys Med* 34 296–299

Jaffe H L (1930) The resorption of bone *Arch Surg* 20 355–385

Landoff G A (1942) Experimentelle Untersuchungen uber die Knochenatrophie" infolge einer Immobilization und einer akuten Arthritis Chemische histologische Untersuchungen am Kaninchen *Acta chir scand* Suppl 71

Lenggenhager K (19 6) Neue Anschauungen uber Genese und Therapie der akuten kleinfleckigen Sudeckschen Knochendystrophie *Helv chir Acta* 23 309–323

McPherson A, Scales J T & Gordon L H (1961) A method of estimating qualitative changes of blood flow in bone *J Bone Jt Surg* 43 B 791–799

Nordin B E C (1960) Osteomalacia osteoporosis and calcium deficiency *Clin Orthop* 17 235–258

Rieder W (1936) Die akute Knochenatrophie *Dtsch Z Chir* 248 269–331

Semb H (1966 a) Experimental disuse osteoporosis I Acid base status in intramedullary blood from immobilized rabbit tibial bones *Acta Soc Med upsalien* 71 83–95

Semb H (19 6 b) Experimental disuse osteoporosis II Oxygen saturation and oxygen tension in intramedullary blood from immobilized rabbit tibial bones *Acta Soc Med upsalien* 71 96–107

Semb H (1966 c) Plasma clearance of Sr^{85} by bone An attempt to study the rate of blood flow through normal and immobilized bone in dogs *Acta Soc Med upsalien* 71 227 236

Shim S S (1966) Quantitative studies of factors affecting bone blood flow based on bone clearance of radiostrontium (Sr^{85}) *Diss Abstracts* 26 4043

Siggaard Andersen O Engel K, Jorgensen K & Astrup P (1960) A micro method for determination of pH carbon dioxide tension base excess and standard bicarbonate in capillary blood *Scand J clin Lab Invest* 12 172–1 6

Siggaard Andersen O J rgensen K & Naeraa N (1962) Spectroph tometric deter

mination of oxygen saturation in capillary blood. *Scand J clin Lab Invest* 14 298–302

Sundén G (1967) Some aspects of longitudinal bone growth. *Acta orthop scand* Suppl 103

deValderrama J A F & Little, K. (1965) Mechanisms involved in the osteoporotic process. *J Bone Jt Surg* 47 B 193

Whedon G D (1960) Osteoporosis Atrophy of disuse In Rodahl K. (ed.) *Bone as a tissue* McGraw Hill New York, pp 67–82

Acta orthop Scandinav 40 563–570 1969

Radiotherapy Clinic (Head Prof M D L R Holsti) University Central Hospital Helsinki and Department of Surgery (Head Prof. D V M S. Paatsama) College of Veterinary Medicine, Helsinki Finland.

THE EFFECT OF Co^{60} IRRADIATION ON THE PATELLA IN DOGS

PENTTI ROKKANEN PENTTI RISSANEN & SAKI PAATSAMA

Received xi 68

As a sesamoid bone of the knee joint the patella differs in many respects from other bones In radiotherapy of malignant bone or soft tissue tumours of the knee the patella also is frequently subjected to irradiation Moreover radiotherapy has long been used in the treatment of osteoarthritis of the knee joint (*e g* Kepp 1952 Knierer 1957) whereby the patella as a rule falls within the field of irradiation Although lately the operative and medical treatment of osteoarthritis has gained ground radiotherapy is still sometimes applied

In previous papers the effect of Co^{60} irradiation on the menisceal tissue and on the soft tissues of the knee region (Rissanen et al 1968 1969a) and on cancellous and diaphyseal bone (Rissanen et al 1969b c) have been described Since however as a sesamoid bone the patella seems to be in a special position in many respects we have tried also to clarify the effect of Co^{60} irradiation on the patella using histological histochemical and oxytetracycline[1] (OTC) labelling methods and microradiography

MATERIAL AND METHODS

The material consisted of 12 dogs of different breeds *i e* six adult dogs aged 2 11 years and six growing dogs aged about three months at the beginning of the study A 3000 Ci Tele Cobalt Unit (FSD 75 cm dose rate 104 rad/min) was used for irradiation. With the dogs in barbiturate anaesthesia, both knees were irradiated with fields measuring 6 cm × 10 cm using the following single doses

I Adult dogs. Left knee joint 1000 rad right knee joint 4000 rad.
II Growing dogs. Left knee joint, 1000 rad right knee joint 2000 rad.

---

[1] Terramycin® Intramuscular Pfizer

The material was divided into three groups according to the time of sacrifice (A) four days after irradiation, (B) two weeks after irradiation, (C) two months after irradiation.

The samples collected for histological and histochemical studies were fixed in neutral formalin, decalcified by the EDTA method and stained by the Weigert van Gieson, haematoxylin eosin and alcian blue techniques. For OTC fluorescence studies the dogs were given 20 mg of oxytetracycline two days before sacrifice. The samples for these studies and for microradiography were hardened with methylmetacrylate and ground to 100 μ thickness. In microradiography the following values were used: 15 mA, 24 kV, 5 min, FSD 12 cm.

RESULTS

I. Adult Dogs

A. Four days after irradiation the following changes were noted. Histologically and histochemically the articular cartilage was uniform after irradiation with 1000 rad but staining was poor in areas. After 4000 rad fragmentation was observed in the superficial layers of the articular cartilage. The cancellous spaces were acellular but the bone was normal after irradiation with these doses. After 4000 rad incipient regeneration of the bone was seen subchondrally. OTC fluorescence was evenly distributed at the margins of the bone trabeculae after both 1000 rad and 4000 rad. In addition OTC fluorescence was observed in areas of the cancellous spaces. Microradiographs revealed after 1000 rad an otherwise normal bone structure but in the cancellous spaces new mineralized areas occurred. This phenomenon was more extensively observed after irradiation with 4000 rad.

B. Two weeks after irradiation the following changes were noted. Histologically and histochemically fragmentation of the articular cartilage was seen after 1000 rad and 4000 rad. The cancellous spaces were acellular and the bone was partly anuclear. OTC fluorescence was very scanty after irradiation with both 1000 rad and 4000 rad.

Figure 1. Microradiograph of the patella of an adult dog taken two months after irradiation with a single dose of 1000 rad. The density of the bone trabeculae is decreased and new mineralized areas are seen at their margins signifying regeneration. × 100

Figure 2. Micrograph of the patellar articular cartilage of a growing dog taken four days after irradiation with a single dose of 1000 rad. The articular cartilage shows fragmentation and decreased metachromasia. Alcian blue. × 100





except in those areas in which microradiography revealed poorly mineralized areas. Such areas were frequently seen in the cancellous spaces. After 4000 rad in particular, the density of the bone trabeculae appeared to be decreased.

C. Two months after irradiation the following changes were noted. Histologically and histochemically the articular cartilage cells were almost entirely anuclear after 1000 rad and 4000 rad and the metachromasia of the matrix was weak and uneven. The cancellous spaces were empty or contained fatty tissue. The bone was anuclear and showed fragmentation in the wide areas. OTC fluorescence was observed only here and there in new mineralized areas and in certain sites at the margins of the cancellous spaces after 1000 rad and not at all after 4000 rad. Microradiography revealed numerous new mineralized areas in the cancellous spaces after 1000 rad and 4000 rad and the density of the bone trabeculae was reduced in areas (Figure 1).

II. *Growing Dogs*

A. Four days after irradiation the following changes were noted. Histologically and histochemically the articular cartilage showed fragmentation after 1000 rad and 2000 rad and the metachromasia was reduced (Figure 2). Subchondrally, aggregations of osteoblasts were seen. The cancellous spaces were poor in cells and regeneration of the bone was observed in areas. The bone trabeculae were poor in nuclei. OTC fluorescence was evenly distributed at the margins of the cancellous spaces after 1000 rad particularly in the subchondral area. After 2000 rad the OTC fluorescence was clearly weaker. Microradiography revealed no changes after irradiation with 1000 rad and 2000 rad.

B. Two weeks after irradiation the following changes were noted. Histologically and histochemically the articular cartilage showed fragmentation in areas after 1000 rad and the metachromasia was scanty and uneven. Both osteoblasts and osteoclasts were seen subchondrally. The cancellous spaces were poor in cells and contained fatty tissue. The bone trabeculae were poor in cells particularly after 2000 rad. In certain areas incipient regeneration was observed at the margins of the bone trabeculae. OTC fluorescence was strong after irradiation with 1000 rad and 2000 rad particularly in the subchondral area (Figure 3) at the margins of the cancellous spaces and in new mineralized areas of

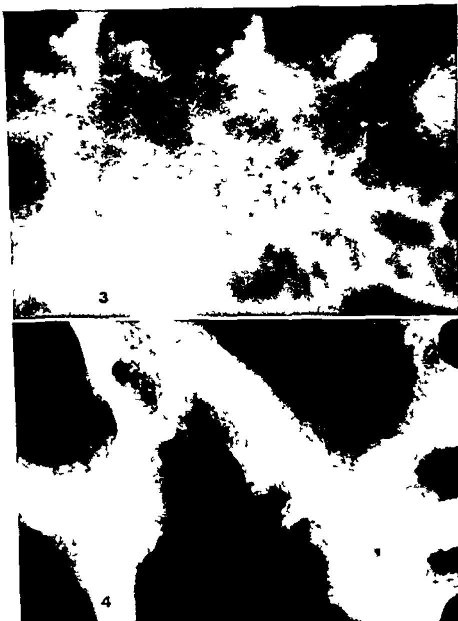


Figure 3 Fluorescence micrograph of the patella of a growing dog taken two weeks after irradiation with a single dose of 9000 rad Abundant fluorescence is seen subchondrally × 100

Figure 4 Microradiograph of the same dog as in Figure 3 Decreased density and erosions are seen at the margins of the bone trabeculae × 100

except in those areas in which microradiography revealed poorly mineralized areas Such areas were frequently seen in the cancellous spaces After 4000 rad in particular, the density of the bone trabeculae appeared to be decreased

C Two months after irradiation the following changes were noted Histologically and histochemically the articular cartilage cells were almost entirely anuclear after 1000 rad and 4000 rad and the metachromasia of the matrix was weak and uneven The cancellous spaces were empty or contained fatty tissue The bone was anuclear and showed fragmentation in the wide areas OTC fluorescence was observed only here and there in new mineralized areas and in certain sites at the margins of the cancellous spaces after 1000 rad and not at all after 4000 rad Microradiography revealed numerous new mineralized areas in the cancellous spaces after 1000 rad and 4000 rad and the density of the bone trabeculae was reduced in areas (Figure 1)

II *Growing Dogs*

A Four days after irradiation the following changes were noted Histologically and histochemically the articular cartilage showed fragmentation after 1000 rad and 2000 rad and the metachromasia was reduced (Figure 2) Subchondrally aggregations of osteoblasts were seen The cancellous spaces were poor in cells and regeneration of the bone was observed in areas The bone trabeculae were poor in nuclei OTC fluorescence was evenly distributed at the margins of the cancellous spaces after 1000 rad particularly in the subchondral area After 2000 rad the OTC fluorescence was clearly weaker Microradiography revealed no changes after irradiation with 1000 rad and 2000 rad

B Two weeks after irradiation the following changes were noted Histologically and histochemically the articular cartilage showed fragmentation in areas after 1000 rad and the metachromasia was scanty and uneven Both osteoblasts and osteoclasts were seen subchondrally The cancellous spaces were poor in cells and contained fatty tissue The bone trabeculae were poor in cells particularly after 2000 rad In certain areas incipient regeneration was observed at the margins of the bone trabeculae OTC fluorescence was strong after irradiation with 1000 rad and 2000 rad particularly in the subchondral area (Figure 3) at the margins of the cancellous spaces and in new mineralized areas of

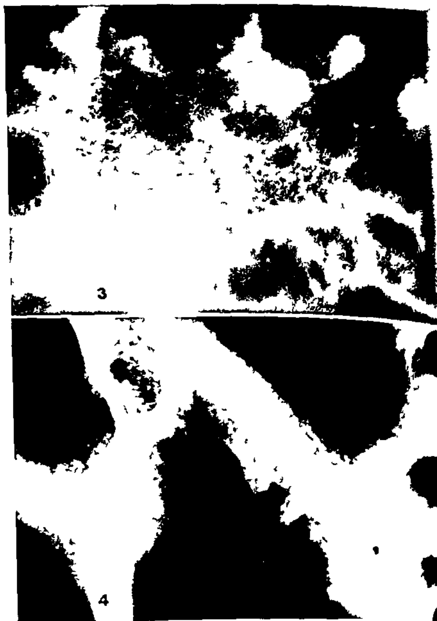


Figure 3 Fluorescence micrograph of the patella of a growing dog tak n two w after irradiation with a single dose of ?000 rad Abundant fluorescence is subchondrally × 100

Figure 4 M croradiograph of the same log as in F gure 3 Decreased density eros ons are seen at the margins of the bone trabeculae × 100

the latter. Microradiography showed a decrease in density of the bone trabeculae, erosions at their margins (Figure 4) and new mineralized areas in the cancellous spaces.

C. Two months after irradiation the following changes were noted. Histologically and histochemically after 1000 rad and 2000 rad the articular cartilage cells were found to be almost entirely nuclear and metachromasia was very scanty. Very slight regeneration was observed subchondrally. The cancellous spaces were more or less empty or they were filled with fatty tissue and the bone trabeculae were nuclear, in particular after irradiation with 2000 rad. After 1000 rad OTC fluorescence was mostly abundant, particularly at the margins of the bone trabeculae and in poorly mineralized areas subchondrally, but areas also occurred in which fluorescence was lacking. After 2000 rad weak fluorescence was only seen here and there. Microradiographically after 1000 rad and 2000 rad the bone trabeculae were thin and showed fragmentation, the density was decreased and poorly mineralized areas were observed in the cancellous spaces.

DISCUSSION

The effect of Co^{60} irradiation with single doses of 1000–4000 rad on the patella was studied in adult and growing dogs. As soon as four days after irradiation both the adult and the growing dogs showed fragmentation and decreased metachromasia of the articular cartilage as well as degenerative changes of the bone. But at the same time signs of regeneration were also observed in the cancellous spaces. Two weeks and two months after irradiation progression of the degenerative changes could be demonstrated both in the articular and the bone trabeculae, but the regenerative processes were also more conspicuous and extensive. The changes showed a correlation with the magnitude of the dose of Co and the age of the dogs, being more marked in the younger dogs.

On comparing the present results with the observations made in cancellous and diaphyseal bone in adult dogs (Rissanen et al. 1963b) and growing dogs (Rissanen et al. 1969c) it was found that the same doses produced clearly greater changes in both the articular cartilage and the cancellous bone of the patella. In explanation of this it may be suggested that when the entire bone is exposed to irradiation it is not capable of resisting and compensating damages caused by irradiation as efficiently as when only part of it is irradiated. In this connection

damage caused to the surrounding soft tissues also seems to play a significant part since with the same doses of irradiation changes were caused in these tissues (Rissanen et al 1968 1969a) On the basis of the present study it is not possible to answer the question as to whether the changes in the cartilage and bone are due to the direct effect of irradiation or secondarily to the damage caused by thrombosis of the blood vessels Considering however the great changes observed in the bone at an early stage and the fact that vascular changes are a later finding it seems probable that the bone lesions develop primarily as a result of the direct effect of irradiation on the bone although later both factors exert a combined influence

Since the doses of Co^{60} used in the present study were much greater than the doses used for instance in the treatment of osteoarthritis of the knee joint no direct conclusions can be drawn concerning the effect of irradiation on the patella in this respect It can however be maintained that the bone tissue is not in all sites nearly so resistant to irradiation as has been alleged (Clemedson & Nelson 1960 Upton 1966) Considering the striking regenerative capacity of the patella it seems possible that irradiation of the knee with smaller doses also might promote the formation of osteophytes and thus contribute to an impairment of osteoarthritis at the patello femoral joint Therefore if radiotherapy is applied to the knee region it seems advisable to avoid irradiation of the patella On the other hand a normal synovial tissue reacts relatively sensitively to irradiation (Rissanen et al 1968) which may lead to the disappearance of swelling and pain

SUMMARY

The effect of Co^{60} irradiation on the patella in dogs was studied by histological histochemical and OTC labelling techniques and by microradiography Single doses of 1000 rad 2000 rad and 4000 rad were used The dogs were sacrificed four days two weeks and two months after irradiation After four days both growing dogs and adult dogs showed fragmentation and decreased metachromasia of the articular cartilage as well as degenerative changes of the bone but signs of regeneration were also observed After two weeks and again after two months both the degenerative and the regenerative changes were more marked On comparing the changes observed with the changes caused by the same doses in cancellous and diaphyseal bone the changes in the patella were found to be more extensive and severe

REFERENCES

Clemedson C.-J. & Nelson A. (1960) In *Mechanism in radiology* ed. M. Errera & A. Forsberg. Academic Press New York and London.
Kepp R. K. (1952) *Grundlagen der Strahlentherapie*. Georg Thieme Verlag. Stuttgart.
Knierer W. (1957) *Praktische Strahlentherapie*. Medica Verlag. Stuttgart.
Rissanen P. Rokkanen P. & Paatsame S. (1968) The effect of Co^{60} irradiation on the synovial tendon and muscle tissues of dogs. *Strahlentherapie* 136 405
Rissanen P. Rokkanen P. & Paatsame S. (1969a) The effect of Co^{60} irradiation on the menisceal. An experimental study on dogs. *Strahlentherapie* 137 68
Rissanen P. Rokkanen P. & Paatsame, S. (1969b) The effect of Co^{60} irradiation on bone in dogs. I. Mature bone. *Strahlentherapie* 137 162
Rissanen P. Rokkanen P. & Paatsame S. (1969c) The effect of Co^{60} irradiation on bone in dogs. II. Growing bone. *Strahlentherapie* 137 344
Upton A. C. (1966) In *Biological basis of radiation therapy* ed. E. Schwartz. J. B. Lippincott Co. London

Acta orthop Scandinav 40 571–576 1969

Zentral Institut für Traumatologie und Orthopädie, Moskau

ALLOPLASTIK VON METALLGELENKEN

M W Wolkow

Received 8.xii 67

Geschichtlich existieren zwei Richtungen in der Transplantation des gesamten Gelenkes Alloplastik und Knochenplastik. Einerseits werden Endoprothesen aus Kunststoffen und Metall andererseits Auto- und Homotransplantate verwendet

Vor 15 Jahren hat man im Ausland und in unserem Land mit der Anwendung von Metall und Akrylprothesen des Hüftgelenkhalses begonnen

Wir haben von 60 in verschiedenen Moskauer Kliniken während der Zeit von 1951 bis 1961 operierten Patienten 46 Fälle zusammengefasst Es stellte sich heraus dass die wiederhergestellte Bewegungsfähigkeit ein bis eineinhalb Jahre nach der Operation verschwandt und dass wieder Schmerzen auftraten Die Kranken mit ankylosierender Spondylarthritis verlieren vollständig die Bewegungsfähigkeit im operierten Gelenk wegen zu schnellen Wucherns des Knochengewebes

Die Versuche der Alloplastik in den Hüftgelenken scheiterten aber nicht nur an den Mangeln des implantierten Materials Der Hauptgrund der Misserfolge bestand darin dass das wichtigste Prinzip der Plastik in den Gelenken – das Prinzip der Homogenität der sich berührenden Flächen – verletzt wurde Die Zusammenfügung des Gelenkknorpels des Empfängers mit dem alloplastischen Gelenkkopf aus einem beliebigen Material führt zur chronischen Reizung des Gewebes innerhalb des Gelenkes und zu Wucherungen, die Ankylose verursachen

Ein neues Verfahren der Alloplastik in den Hüftgelenken wurde von K M Siwasch im Jahre 1956 entwickelt Dieses Verfahren unterscheidet sich grundsätzlich von allen bisherigen

Bei der Entwicklung des neuen Konstruktionsmodells des Metallgelenkes wurden folgende Momente beachtet

1. Sicherung des Zusammenhaltes des Metallgelenks mit den Knochen des Wirtes. Dieser Zusammenhalt kommt dadurch zustande, dass Knochengewebe in die Löcher des diaphysären Teils der Endoprothese und in die Einschnitte der Metallhuftgelenkpfanne einwächst.
2. Schaffen eines Spielraums zwischen dem Metallgelenkkopf und der Gelenkpfanne.
3. Gewährleistung der Haltbarkeit der höchstbelasteten Gelenkteile.

Für die Modernisierung des betreffenden Konstruktionsmodells wurde mathematische Berechnungen vorgenommen. Am Anfang vorgekommene Gelenkbruche und deren Gründe wurden dabei berücksichtigt.

Das Siwasch-Gelenk ist die fabrikmässig hergestellte Metallkonstruktion bestehend aus Hüftgelenkspfanne, Kopf, Hals und diaphysären Teil der Endoprothese. Die Huftgelenkspfanne hat an ihrer Aussenseite zahlreiche Einschnitte, und der diaphysäre Teil hat einen grossen Spielraum, der eine bessere Festigung des diaphysären Teils der Endoprothese gewährleistet. Anfangs wurde die Endoprothese aus Komochrom/Kobalt, Molybdän und Chrom/ hergestellt. Heute jedoch wird sie im Werk des Zentralen Instituts fur Traumatologie und Orthopädie aus Titan hergestellt. Die heutige Endoprothese wiegt anstatt 600 gr. nur 300 gr.

Viele Experimente wurden vor der klinischen Anwendung der Endoprothese vorgenommen. Das Versuchsgut bestand aus 38 Hunden, die Untersuchungszeit erstreckte sich auf einen Zeitraum von 3 Tagen bis zu 3½ Jahren. Das Gewebe nach Anwendung der Endoprothese wurde histologisch und rontgenologisch untersucht. Folgende Prozesse waren zu beobachten: das Knochengewebe wuchs schnell in die Locher des Metallgelenks ein. Dieser Prozess verursachte eine Art von fester Bindung zwischen der Huftgelenkpfanne und dem Huftgelenkkopf des Metallgelenkes und den entsprechenden Knochen des Wirtes. Um den Hals und an der Aussenseite des Metallgelenkkopfes entstand eine Kapsel aus Bindegewebe.

Die Kapsel hatte eine glatte und glänzende Oberfläche. Histologische Untersuchungen haben gezeigt, dass das Hineinwachsen des neu gebildeten Gewebes des Wirtes in die Einschnitte die reparativen Prozesse einstellte.

Im Jahre 1969 wurde die neue Endoprothese klinisch verwandt. Es wurde 158 Patienten operiert. Die meisten von ihnen (110 Kranke)

Figur 1



Figur 2

Figur 1 und 2. Spondylarthritis. Hüftgelenkankylose in Abweichung von der Extremitätachse

Figur 3 Nach der Operation der rechten Seite

Figur 4 Nach der zweiten Operation

litten an schwersten unheilbaren Gelenkdeformationen infolge der rheumatoiden ankylosierenden Spondylarthritis bzw der Strompel Marie Bechterew schen Krankheit 27 Patienten wurden wegen Ankylose nach Tuberkulose operiert 4 Patienten hatten Oberschenkel halsbruche mit dadurch verursachter Lysis des Kopfes und 17 operierte Patienten litten an *Huftgelenksarthrose*

Der volle Ersatz des Huftgelenks durch ein Metallgelenk erfordert eine weite Resektion des oberen Teils des Oberschenkels Der Hüftgelenkshals wird unmittelbar unter dem Trochanter minor reseziert Besonders zweckmassig ist solch eine grosse Resektion bei der ankylosierenden Arthritis da sie fur diese Krankheit charakteristische *Rezidive in Form knocherner Wucherungen ausschliesst*

Immobilisierung fur 7–10 Tage wird mit Hilfe von Gipshalbverbänden geschaffen Danach folgt Mechanotherapie Massage und Gymnastik auf dem Langsrahmen und auf der Siwasch Sonderschiene

Es fiel sehr schwer bei ankylosierender Spondylarthritis die Bewegungsfähigkeit wiederherzustellen da sie infolge jahrelanger Ankylose (bis zu 16 Jahren) fehlte Nicht selten traten dabei Fehlstellungen auf

Der Grenzwert des Winkels der in den ersten 4–6 Wochen wiederhergestellten passiven Bewegungsfahigkeit betrug 45 –60 Die aktive Bewegungsfahigkeit trat nach der 4 Woche wieder auf Nur bei 4 Kranken mit scharf ausgepragter Muskelatrophie trat sie erst nach der 8 Woche und noch spater auf 6 Wochen nach der Operation hat man den Kranken erlaubt mit Krücken zu gehen wenn dabei die Fehlstellung besonders die Spreizstellung des zweiten Oberschenkelknochens sie nicht am Gehen hinderte 3½–4 Monate nach der ersten Operation wurde in diesen Fällen eine Alloplastik am zweiten Huftgelenk vorgenommen nach der die Kranken auf Krücken gehen konnten

Bemerkenswert ist die Tatsache dass das implantierte Huftgelenk in allen Fällen Stützfahigkeit besass Die meissten Kranken konnten 2½–3 Monate nach der Operation das operierte Bein vollig belasten

Besondern wirkungsvoll zeigte sich die Siwasch Methode bei einem vollen Ersatz des Hüftgelenkes im Falle einer schweren Ankylose infolge von rheumatoider Arthritis Die Kranken wurden in den Abteilungen fur Wiederherstellungschirurgie und fur rheumatoide Arthritis des Zentralen Instituts für Traumatologie und Orthopädie in Moskau operiert

Der Patient G W J ist 40 Jahre alt Seit 1943 litt er an Spondyl

arthritis Die letzten 6 Jahre vor der Operation konnte er wegen einer völligen Ankylose der beiden Hüftgelenke nicht gehen (Ein Bein gespreizt das andere reduziert) Die beiden Hüftgelenke wurden nacheinander im April 1963 und im Januar 1964 ersetzt Seit der ersten Operation sind also 3 und seit der zweiten 2½ Jahre vergangen Dank der wiederhergestellten Bewegungs- und Stützfähigkeit in beiden Hüftgelenken kann der Kranke heute frei gehen (p v 1 2 3 4)

Der Ersatz der beiden Gelenkflächen mit einer Vergrösserung des Bewegungswinkels weit über die Knochengrenze hat sich also bewährt Auf diesem Grundprinzip wurden heute Finger- und Kniegelenkprothesen entwickelt 10 Operationen an Fingergelenken wurden schon durchgeführt Eine schöpferische Zusammenarbeit zwischen dem Institut für chirurgische Ausrüstung und Instrumente und dem Zentralen Institut für Traumatologie und Orthopädie ist erforderlich um weitere Erfolge zu erzielen

SUMMARY

The author describes a new endoprosthesis for the hip-joint constructed by Siwash The prosthesis is in one piece The acetabular part has on its convex surface multiple perforated layers whereby a very good fixation is accomplished by the ingrowing bone Also the femoral stem of the prosthesis is perforated for the same reason A total of 158 patients have been operated with resection of the osteoarthritic hip-joint and reconstruction with the Siwash prosthesis The results are very encouraging and are discussed in some detail

Acta orthop Scandinav 40 577-586 1969

Zentral Institut fur Traumatologie und Orthopadie Moskau

DIE FORSCHUNGSERGEBNISSE DER SOWJETISCHEN ORTHOPADIE IN DER HOMO PLASTISCHEN CHIRURGIE VON GELENKEN

M W Wolkow

Received 8 xii 67

Es ist allgemein bekannt dass für die Behebung der Defekte des Stütz bewegungsapparates bei den Rekonstruktions Operationen das beste Verpflanzungsmaterial in der Wiederherstellungschirurgie das Autogewebe das heisst das eigene Gewebe des Patienten ist Unter bestimmten Verhaltnissen ist die zusätzliche Operation zwecks einer Gewebeentnahme kontraindiziert in anderen Fallen ist sie uner wunscht (zum Beispiel bei kleinen Kindern fuhrt der zusatzliche Eingriff zu Zeitverlangerung der Operation und Narkose) manchmal ist dieser zusätzliche Eingriff sogar unmoglich zum Beispiel wenn das Einverständnis der Eltern des erkrankten Kindes oder das Einver standnis des erwachsenen Patienten auf einen zusätzlichen Schnitt an der gesunden Extremität nicht vorliegt Weiterhin ist ein zusätzlicher Eingriff unmoglich bei Systemschäden des Skelettes oder bei ausgedehnten Hautverleteungen sowie bei ausgedehnten Korperverbrennungen

Im Zentral Institut fur Traumatologie und Orthopadie existiert schon seit 12 Jahren ein Laboratorium für Gewebekonservierung mit einer grossen Knochenbank Fur dieses Laboratorium wurde ein spezielles Gebäude erbaut wodurch sowohl die wissenschaftliche als auch die praktische Tatigkeit des Labors gefordert wurde In den 17 anderen Instituten der Traumatologie und Orthopädie die sich in anderen Stadten unseres Landes befinden gibt es auch solche Gewebebanken

Das sowjetische Gesetz uber die obligatorische Sektion aller Verstorbenen forderte die Entwicklung der homoplastischen Chirurgie in unserem Lande

Wenn bei den ersten Schritten der homoplastischen Chirurgie nur winzige Gewebestuckchen ausgenutzt wurden weil die Frage der Re

aktionen des Empfängers auf das Gewebe des Spenders und die Frage der Gewebekonservierung erst studiert wurden, so werden heute in der orthopädischen Praxis in gleicher Weise Knochen Haut Nervenstämme Faszien Bänder Gelenkenden des Knochens sogar ganze Gelenke und sowohl andere Gewebe als auch Leichenblut verbreitet ausgenutzt

Den grössten Anwendungskreis erlangte die Konservierung bei einer Temperatur von — 70 während 24 Stunden mit zulässiger Aufbewahrung der Gewebe in der Folgezeit im Laufe von 6 Monaten bis zu 1 Jahr bei einer Temperatur von — 30 C Bei uns konserviert man Knochengewebe Nervenstämme Sehnen Haut

Die Konservierungsmethoden der Tiefkühlung befriedigen uns nicht immer dabei sind teure Kühlapparate erforderlich Solche sind jetzt in unserem Lande zugänglich Aus diesem Grunde interessieren wir uns für die chemischen Methoden Die Konservierung des noch frischen Knochens der von Leichen entnommen wird ist in den Briketts aus Paraffin und Polymeren sehr bequem Von den Experimenten sind wir zur Klinik hinübergewechselt Die Polymerbriketts ermöglichen uns die Knochen 2 Jahre lang aufzubewahren Dabei kommt in ihnen keine Störung der Fermentprozesse vor (150 Operationen)

Die Gewebeentnahme bei Leichen unter sterilen Bedingungen ist eine zeit und kraftraubende Arbeit Deshalb interessiert uns besonders der Vorschlag unseres Doktors L N Sautin für die Sterilisation des lyophilisierten Homoknochens Kobaltgammastrahlen auszunutzen Dies ermöglicht uns weniger streng aseptische Bedingungen bei der Gewebeentnahme einzuhalten Weil lyophilisiertes Gewebe sproder ist als gefrorenes benutzen es die Chirurgen seltener und weniger gern

Die ausgedehnteste und verbreitetste Anwendung in der Orthopädie erlangte von den verschiedenen Homogeweben der artfremde Knochen In den letzten 12 Jahren wurden im Zentral Institut fur Traumatologie und Orthopädie etwa 2 000 Operationen mit Verpflanzung eines Homoknochens durchgefuhrt Zu diesem Zweck wurden 3787 Homotransplantate ausgenützt In allen Fallen wurde Knochengewebe von Leichen von Menschen benützt deres plotzlicher Tod durch ein Trauma einen Infarkt oder einen Insult hervorgerufen wurde Als Kontraindikationen fur eine Gewebeentnahme kamen in Betracht entzundliche Prozesse sowie venerische und infektiose Krankheiten Die entnommenen Konservierungsgewebe vernichtet man wenn eine der obengenannten Todesursachen vorliegt

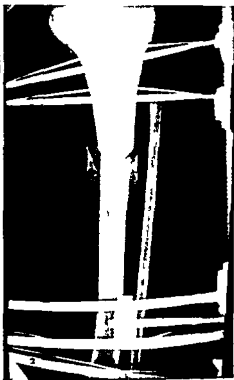
Grundindikationen für eine Ersetzung der Knochendefekte sind Pseudarthrosen (450 Operationen), Defekte nach einer Geschwulstentfernung (636 Operationen). Ausserdem wird der Homoknochen auch als intramedullärer Fixator angewandt, zum Beispiel bei der Durchführung von Gelenkarthrodesen (189 Operationen), bei der Koaptation von Knochenfragmenten bei Osteotomien (100 Operationen), bei der Frakturbehandlung (224 Operationen), weiterhin bei Wirbelsäulenfixierungen wegen Skoliosis (201 Operation) und bei anderen Indikationen. Wenn wir anfänglich die Kombinationsplastik mit Auto- und Homotransplantaten durchführten, so beschränken wir uns heute in der Regel nur auf die Homoplastik, und nur in Ausnahmefällen, zum Beispiel bei rezidivierenden angeborenen Pseudarthrosen, stabilisieren wir die Homotransplantate mit Autotransplantaten.

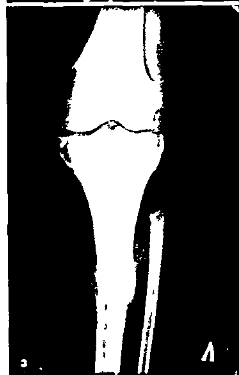
In unserem Lande existieren zwei Ersetzungsmethoden bei grossen Knochendefekten: die mit grossen segmentaren Transplantaten und die mit dünnen Knochenplatten – das ist die sogenannte von uns ausgearbeitete Methode vom Typ eines Reisigbündels. Der Vorteil der zweiten Methode besteht im schnelleren Umbau des Knochens, der Vorteil der ersten Methode in der Möglichkeit, das Homotransplantat in der notwendigen Grösse und Form zu wählen und auszunutzen. In dieser Hinsicht ist das Gelenkendenverpflanzungsverfahren der sowjetischen Orthopäden interessant.

Beim Vorhandensein eines grossen Defektes nicht am Knochenende, sondern am Knochenschaft wird von uns neben dem segmentaren Transplantat, das sich mit Hilfe eines Kompressionsapparates gewöhnlich befestigen lässt, die Plastik mit 8–10 dünnen parallel dicht aneinandergelegten Homoplatten angewandt.

Die Idee der Gelenkverpflanzung stammt vom deutschen Chirurgen Lexer, aber in seiner Zeit konnte man keinerlei Erfolge erreichen. In unserem Institut hat Doktor V. S. Immaliew bei den Experimenten mit Hunden die Methodik der Gelenkendenverpflanzung angewandt und dann wurde diese Methodik in der Klinik ausgenutzt. Eine erste derartige Operation führte Frau Doktor M. I. Panowa durch: sie machte einen Ersatz der oberen Hälfte der Hüfte bei einem Patienten mit infektiöser Koxit. 7 Jahre nach der Operation kann der Patient ausgezeichnet den Fuss in vollem Bewegungsumfang gebrauchen. Bis heute wurden im Zentral Institut für Traumatologie und Orthopädie schon 90 gleichartige Operationen durchgeführt. Man versucht auch gleichzeitig zwei Gelenkenden zu verpflanzen. In einigen Fällen kom







Figur 1 Die Riesenzellengeschwulst der Tibia bei einem Patienten im Alter von 35 Jahren.

Figur 2 Resektion und nachfolgende Homoplastik durch ein Gelenkende

Figur 3 Die Spätergebnisse nach 5 Jahren



Figur 4 a Die Patienten mit maligner Riesenzellengeschwulst

Figur 4 b Nach der Resektion Der Defekt ist mit dem Homotransplantat temperär ausgefullt

Figur 4-c 4 Monate später wurde an ihm das Gelenkhomotransplantat befestigt

Figur 4-d Die Spatergebnisse nach einem Jahr

men Komplikationen vor und zwar Nekrose des nichtumgebauten Homotransplantates in 20 % der Falle und Arthrosen und Kontrakturen – auch in 20 % der Falle

Insgesamt sind in der Sowjetunion zur Zeit mehr als 150 Verpflanzungsoperationen von Gelenkenden durchgefuhrt

Als Beispiel des vollstandigen Erfolgresultates von Verpflanzungen der Gelenkenden konnen folgende Beobachtungen dienen

Der Patient P 35 Jahre alt wurde vor 5 Jahren wegen eines Riesenzellentumors des proximalen Tibiaendes operiert Es wurde die Knochenresektion mit anschliessendem Ersatz des Defektes durch ein Gelenkhomotransplantat durchgefuhrt Nach 5 Jahren zeigte die Röntgenaufnahme vollstandige Wiederherstellung des Knochengelenkendes Der Patient lauft ohne fremde Hilfe der Bewegungsumfang ist vollstandig normal (s 1 2 3)

Die 12jahrige Patientin K wurde vor 2 Jahren wegen eines Riesenzellentumors des proximalen Humerusknochenendes operiert Es wurde anschliessend der Defekt Ersatz durch ein Gelenkhomotransplantat durchgefuhrt Zuerst wurde die Geschwulst entfernt und der Distraktor



Figur 5. Die Spätergebnisse nach zwei Jahren. Bei der Patientin wurde die Verpflanzung des M. trapezius an dem M. deltoideus vorgenommen

Figur 6. Die Verpflanzung des gesamten Gelenkes nach 4 Jahren



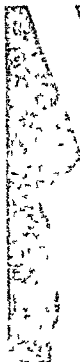
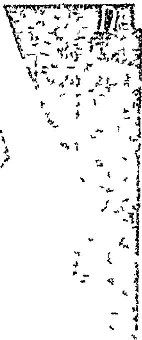
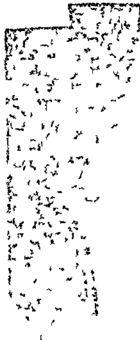
Figur 7 Die Spätergebnisse nach 4 Jahren

aus Homoknochen eingesetzt. Und nach 4 Monaten wurde auf dem schon angewachsenen Stift das Gelenkhomotransplantat eingesetzt. Die Patientin hat nach der Verpflanzung des M. trapezius auf den M. deltoideus befriedigende Bewegungsmöglichkeiten (s. 4. 5).

Dank des erfolgreichen Ersatzes eines Knochengelenkendes durch ein Homotransplantat, der bei vielen Patienten unter ständiger Beobachtung (bis zu 7 Jahren Beobachtungszeit) durchgeführt wurde, sind für Verpflanzungen gesamter Gelenkkomplexe die Voraussetzungen geschaffen worden.

Bei Experimenten mit Hunden wurde bei Verpflanzungen die Methodik der Anwendung von gefrorenen Homogelenken bearbeitet. Es wurde bei dem Hund eine Resektion des Kniegelenkes durchgeführt, das Kniegelenk wurde für die Anwendung eines anderen Experimentes konserviert und aufbewahrt. Während der Ausarbeitung der Operationsmethodik hatten wir grosse Schwierigkeiten bei der Fixerung von Knochenfragmenten an der Tibia. Bei einer Reihe von Experimenten gelang es uns, eine stabile Fixierung der Fragmente mit Hilfe von Kompressionsapparaten und eines intramedullären Stiftes aus Homoknochen oder Metallplatten zu verwirklichen. Das Homotransplantat hatte Y- oder Z-Form oder die Form des „russischen Schlosses" nach S. T. Sazepin. Am Homogelenkkomplex des Kniegelenkes waren die




Figur 9 Der Patient nach der tuberkulosen Gonitis und der Verpflanzung des gesamten Gelenkes Die Spatergebnisse nach 2 Jahren



Kniegelenken durchgefuhrt darunter 15 an Hunden und 6 an Affen

Die erste Verpflanzung des gesamten Kniegelenkes wurde im Marz 1962 *in der Klinik des Zentral Instituts für Traumatologie und Orthopadie* vorgenommen

Schauen wir uns folgende Beispiele an

Die Patientin N 22 Jahre alt Defekt am Kniegelenk nach Entfernung des Synovioms konnte sich während der Zeit von 4 Jahren nicht auf die Extremität stutzen Im Marz 1962 wurde die Verpflanzung des Gelenkkomplexes durchgefuhrt (A S Imamaliew) Nach 3 Jahren kann die Patienten mit voller Belastung der Extremitat laufen Die Bewegungen im Kniegelenk sind bis zu 50 erreicht worden (v 6 7)

Der Patient I 19 Jahre alt hatte eine Ankylose des linken Kniegelenkes nach Tuberkulose und Resektion Er hatte Schmerzen und Wackelbewegungen im Gelenk Vor 14 Monaten wurde die Resektion des Kniegelenkes und die Verpflanzung des Homogelenkes durchgefuhrt (M W Wolkow) Die Fixierung geschah mit Metallplatten mit Schrauben Die 1jahrigen Ergebnisse waren befriedigend die Bewegungen befanden sich in den Grenzen von 110 (v 8 9)

Die Resultate nach der Verpflanzung von Homogelenken beim Menschen fordern weitere und genauere Untersuchungen und sind noch nicht vollstandig gelost

SUMMARY

Deep frozen bone homografts are very often used within the field of orthopaedic surgery in the USSR This is so not only in the recon struction of minor skeletal defects (e g fractures non unions osteoto mies) but also in the replacement of major defects e g after joint resection In our institute more than 2,000 operations have been per formed with the use of homologous bone grafts Of these 90 comprise the homotransplantation of one articular end in the hip or the knee joint The results show good healing of the homograft with good clinical function in about 60 per cent of the cases In about 20 per cent there was permanent necrosis of the graft and in another 20 per cent osteoarthritis and/or contractures gave a less satisfactory joint function A total homologous joint transplantation has also been per formed in some cases The biological problems and the surgical tech nique with these methods are discussed and some representative cases presented in detail

Acta orthop Scandinav 40 587–601 1969

Department of Orthopaedics and Hand Clinic Kaplan Hospital, Rehovot
and Zamenhof Clinic, Tel Aviv Israel

PRIMARY REPAIR WITHOUT IMMOBILIZATION OF FLEXOR TENDON DIVISION WITHIN THE DIGITAL SHEATH

An Experimental and Clinical Study

ISIDOR KESSLER & FUAD NISSIM

Received 22 v 68

In spite of some recent technical improvement in the management of tendon injuries no real progress has been achieved in avoiding the tendency to adhesion formation around flexor tendons injured or repaired within the digital sheath This situation equally concerns surgeons who tend to repair digital flexor tendons by primary end to-end suture as well as those who prefer the secondary repair by free tendon replacement

As most statistics dealing with the subject indicate any method regardless of technical refinements unfortunately results in relatively high rates of failure In an attempt to avoid or at least to diminish the amount of adhesion responsible for the failures a large series of investigations has been performed trying mainly to isolate the tendon from the surrounding tissues Plastic materials such as cellophane polyethylene millipore etc vitalium stainless steel and even some biological structures have been used as adhesion blocking artificial sheaths (Ashley et al 1959 Burman & Umansky 1930 Farmer 1947 Gonsalez 1949 Cucukdjian 1956 Koth & Sewell 1955 McKee 1945 Weckesser et al 1949) Without dwelling on further details it is only to be noted that none of the methods or materials mentioned has been accepted in surgical practice in spite of enthusiastic initial reports Obviously healing of the sutured tendon is consequently delayed or even seriously impaired as a result of surrounding cellular activity (Potenza 1962 Skoog & Persson 1954) if an artificial adhesion blocking sheath is used Therefore a more physiologic approach is needed for

preventing or altering the nature of adhesions during the course of healing of the repaired tendon

With these considerations in mind we examined the early stages following primary repair of divided digital flexor tendons As has been frequently observed an almost full range of movement could be demonstrated immediately after an end to-end anastomosis Limitation of movement develops later during the process of healing when immobilization prevents the normal gliding excursions of the tendon In this period fibrous tissue proliferation takes place not only between the sutured tendon ends but also between the longitudinal surfaces of the tendon and the surrounding tissues Finally adhesions intimately involve the respective structures resulting in various degrees of limitation of the normal tendon excursion

The idea of preserving the initial movements of the repaired tendon by early mobilization is not a new one Lexer (1911) emphasized the importance of avoiding adhesions by careful suturing and early motion i e, six days after operation During the years his outlook was gradually abandoned mostly due to technical failures that often led to separation of the sutured tendon ends and massive fibrotic reaction

The problem of early motion or rest during the time of healing of digital flexor tendons is still very controversial Although many hand surgeons strongly recommend immobilization as a prerequisite to any kind of tendon repair (Campbell Reid 1960 Koch 1946 Littler 1959 McCash 1945 Rank & Wakefield 1960 Verdan 1960) others believe that early motion closely supervised by the surgeon could contribute to reducing adhesions between the tendon and its surrounding tissue (Buchner & Hofman 1959 Bunnell 1956 Lange 1951 Murray 1960 Young & Harmon 1960) It has been the main purpose of the present study to add some details to the data already known on this topic The clinical part of the study which covers a very small series of seven cases should be regarded as preliminary

MATERIAL AND METHODS

A Experimental

Twenty five young adult chickens (weight 1.3 to 1 7 kg) were selected from a single strain Chickens were chosen as experimental animals because of the anatomical resemblance between their digital flexors and the corresponding flexors of the human hand as reported by Lindsay & Thompson (1960) and Lindsay et al. et al ((1960) In ten of them the second long digit of the right extremity was operated. The others were operated bilaterally on the same digit. The extremities of the animals were prepared by washing with water and re ular soap followed by a



Figure 1 The surgical approach in chickens A mid lateral incision reveals anatomical details very close to the human The insertion of the sublimis has been detached and the tendon is to be resected at the level of the upper border of the skin wound

five minute treatment of the skin with 1 per cent Cetablon Half an hour before operation 20 mg of Pethidin was injected intramuscularly As anaesthetic agent we used open ether The operations were performed under rubber tourniquet in strictly aseptic conditions The skin incision was made in a midlateral plane as is usually done in humans. The tendon sheath was exposed and the part over the medial and half of the basal phalanges was completely excised The flexor sublimis tendon was detached from its insertion then pulled down with a forceps and resected at the level of the upper border of the skin wound (Figure 1) The deep flexor tendon was elevated as atraumatically as possible and the initial steps of the suture were performed before its division A new type of suture technique was employed in an attempt to achieve an anastomosis strong enough to withstand the tension of the non immobilized tendon This suture was developed on the basis of the original Masson Allen s suture using twisted wire No 8/0 008 It consists of four knots grasping the substance of the tendon and forming a regular intratendinous rectangle Further details of the suture technique are to be seen in Figure 2

After completion of the anastomosis the skin was closed by interrupted silk sutures and a light gauze dressing was applied to the operated digit only The chickens were injected with 500 000 units of procaine penicillin In order to check the condition of the suture a roentgenographic examination was always performed at the end of the operation Then the chickens were placed in cells with a net covered floor This arrangement was especially designed to set up conditions under which any attempt at walking would be accompanied by grasping d gital motion. It was considered to be the best possible way to obtain some kind of active exercises after surgery The animals were re examined in groups at weekly intervals, noting the stages of healing and adhesions The first group was sacrificed one week and the last group six weeks after surgery The sutured tendons were exposed and their state carefully examined. The results of these experiments are summarized as follows



Figure 2 The proposed technique in its different stages 1 and 2 represent the two diagonally located knots grasping approximately one fourth of the tendon substance on each side Needles pass in the opposite side of the same fragment grasping a similar part of the tendon (3) The three last stages (4 5 and 6) represent the intratendinous part of the suture 7 and the roentgenogram show the rectangular shape of the suture with the repair completed

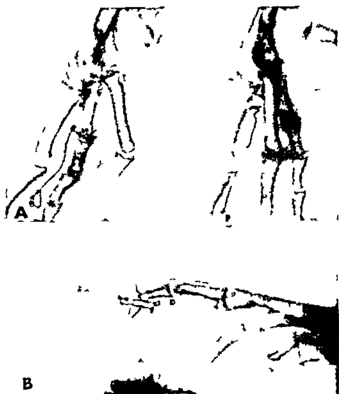


Figure 3 An example of ruptured grasping suture with retracted proximal end (A) and an intact suture (B) for comparison

In 17 operations the wire suture completely ruptured in its central part and the proximal end of the tendon retracted high into the palm All the ruptures occurred in the first week after operation and were clearly demonstrated in the roentgenographic control (Figure 3) It is to be noted that *not in a single case was the wire* separated from its insertion in the tendon The suture always ruptured centrally and the proximal end of the tendon retracted including its part of the wire

In 19 operations the suture was found to be intact and in the other 4 the suture ruptured only partially

The almost equal distribution of ruptured and intact suture gave us an opportunity to re examine both conditions at intervals as mentioned above

In instances with *ruptured* sutures, dissection at the end of the first week revealed slightly thickened yellowish tendon ends and a great gap with marked exudative reaction (Figure 4) Microscopically there were mononuclear cells much fibrin and beginning capillary proliferation At the end of the second week the proximal and distal fragments of the tendon were found to be well surrounded by granulation tissue which also occupied the gap between them (Figure 5) At that stage both stumps showed active proliferation of tenoblasts with a number of mitoses and increasing proliferation of capillaries. Tenoblasts also invaded the gap Fibroblastic reaction increased gradually to a point at which dissection at the



Figure 4. The appearance of a ruptured suture as of and after one week. Note the thickness of the tendon ends.

Figure 5. Dissection of an experiment with ruptured suture two weeks after surgery. Note a well developed granulation tissue which intimately includes the tendon ends.





Figure 6. Four weeks after surgery in experiments with intact suture dissection revealed a well healed smooth and shiny tendon.

end of the fourth week revealed the separated tendon ends to be so intimately included into dense fibrous tissue that only their more proximal and distal parts could be identified. In instances with *intact* suture the process of healing developed quite differently. At the end of the first week dissection revealed well approximated tendon ends somewhat swollen and mild exudative reaction. Microscopic examination showed fusion of the stumps by active proliferation of fibroblasts. The sur

rounding reaction was represented by mononuclear cells and proliferating capillaries At the end of the second week the inflammatory reaction decreased the anastomosis was found to be unchanged and proximal traction produced almost complete flexion of the corresponding digit A mild fibrotic reaction could be observed after three weeks Microscopically the stumps showed marked increase in fibroblastic and vascular proliferation and decrease in other cellular reaction *Fibrosis was shown as fine bundles connecting the tendon with the surrounding* tissues These changes were more pronounced at the end of the fourth week and remained almost unchanged afterwards At this stage dissection revealed a well healed, smooth and shiny tendon slightly thickened at the site of suture (Figure 6) It is to be noted that in all instances with intact sutures good range of flexion could be demonstrated when traction was placed on the tendon proximal to the anastomosis These chickens had also shown good *in vivo* function of the repaired digit which joined the rest in grasping the wires of the cells

In the four instances with partially ruptured sutures at the end of the second and third weeks dissection revealed moderate to severe fibrotic reaction mainly in the region of the gap

B Clinical

The proposed "grasping suture was applied in the primary treatment of divided extensor tendons of the hand and wrist in seventeen cases which were not included in the present report. During the same period only seven cases of divided digital flexor tendons happened to be under out treatment In the evaluation of early movements, those cases seem to be of sufficient interest to justify a report of each one separately

Case 1

L.J., a seventeen year old technician was admitted to us several hours after he had injured his left index finger with a metal plate. The examination revealed a fresh wound with slightly crushed borders over the proximal interphalangeal joint Although both interphalangeal joints were passively free no active flexion could be obtained Under axillary block anaesthesia the original wound was extended and the palmar side of the finger exposed Both flexor tendons were found to be divided and the proximal interphalangeal joint open After excision of the sheath the sublimis tendon was pulled down and cut as high as possible The ends of the deep flexor were approximated and sutured in a slightly different manner from the technique described so far After closing the wound a light gauze dressing was *applied leaving the hand free The patient* was seen every day in the first week and controlled movements in all the fingers were encouraged starting from the third day Physical therapy was advised after three weeks because of a mild stiffness of the proximal interphalangeal joint. The patient returned to his work forty one days after surgery In the last examination seven month later movements were found to be as follows flexion of the proximal interphalangeal joint to 90 degrees, extension to 180 degrees flexion of the distal interphalangeal joint to 140 degrees, extension to 180 degrees The finger was able to touch the palm without any practical impairment of the normal function (Figure 7)

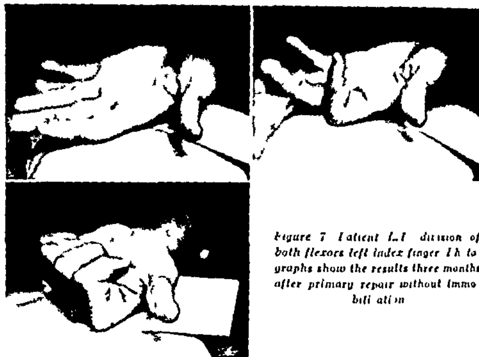


Figure 7. Patient L.I. division of both flexors left index finger. Photographs show the results three months after primary repair without immobilization.

Case

B.J., a twenty two year old technician, was examined six hours after injury. He sustained a blow with a sharp instrument causing a small penetrating wound between the fourth and fifth fingers at a point just distal to the distal palmar crease. Passive movements were free but no active flexion was possible. Under ulnar block anaesthesia the flexor sheath was exposed and a complete division of both flexor tendons was revealed. The sublimis was pulled down and excised and the cut ends of the deep flexor were anastomosed by "grasping" wire suture. It is to be noted that the proximal pulley was misplaced an insufficient distance to the line of suture. In full flexion the suture line became opposite and at the same level to the pulley. The skin was closed, light dressing applied and active exercises started the next day. Two weeks later the patient was able to flex the proximal interphalangeal joint to 1 0 degrees and the distal interphalangeal joint to 140 degrees. Extension reached 160 degrees in the proximal interphalangeal joint and could not be increased passively. Any attempt at active verflexion elicited a painful response. Without further improvement in the range of movements he returned to work 34 days after operation. Upon the assumption that incorrect location of the proximal pulley was responsible for the persistent limitation of flexion, a new surgical correction was advised. One month later through a small lateral incision the pulley was divided and the patient encouraged to active movements. In the last examination (six months after surgery) movements were noted to be as follows: flexion of the proximal interphalangeal joint reached 90 degrees, extension reached 1 0 degrees, flexion of the distal interphalangeal joint





Figure 8 Division of both flexors right little finger The result six months after primary repair without immobilization

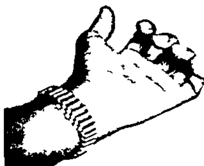
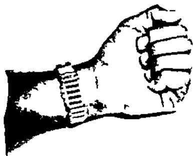




Figure 9 Patient S Z photographs show the end result after primary suture of the deep flexor tendon of the third finger left hand

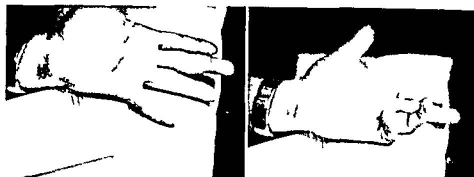


Figure 10 Case K H result obtained from an end to end anastomosis of a divided deep flexor tendon at the level of the distal interphalangeal joint Active movements started immediately after surgery

was noted to be 1 0 degrees extension 150 degrees The finger was able to touch the palmar crease (Figure 8)

Case 3

S Z an eighteen year old factory worker was admitted to us about four hours after his left hand was wounded by broken glass Examination revealed a cut deep flexor tendon of the third finger Under axillary block anaesthesia the flexor sheath was exposed and an additional division of the medial insertion of the sublimis tendon was observed The medial insertion of the sublimis was re attached and the cut ends of the deep flexor were identified and anastomosed with grasping suture Active movements started five days later The patient returned to his work 31 days after operation The last examination (two months after injury) revealed full range of flexion in the interphalangeal joints of the repaired finger (Figure 9)

Case 4

K H a seventeen year old student was admitted to us three hours after he had injured his left little finger in a press A deep grease covered wound with crushed borders over the distal interphalangeal joint was observed The joint was open and the deep flexor tendon divided Anastomosis in that case was performed by direct suture of the proximal end into fish mouth opening of the distal end. Active movements started the next day He returned to his mechanical practice 29 days after surgery The last examination (14 months later) revealed active flexion of the distal interphalangeal joint to 100 degrees extension up to 150 degrees (Figure 10)

Case 5

M A a thirty year old sailor was seen at our department 24 hours after he had injured his right thumb on a broken glass Examination revealed a clean wound over the volar surface of the basal phalanx and loss of active flexion in the inter phalangeal joint Under axillary block anaesthesia the wound was extended and the flexor sheath exposed The distal end of the cut long flexor was found at the depth of the wound The proximal end was also identified and sutured to the distal by grasping suture Active movements started on the next day Six weeks later the



Figure 11 Patient M A Result obtained eight months after primary grasping suture of a divided long flexor tendon of the right thumb

active movements were noted to be as follows extension of the interphalangeal joint to 190 degrees flexion to 140 degrees Since no further improvement of the movements was obtained during the next few months and the patient was not satisfied with the range of motion surgery was repeated three months later Through a small lateral incision the suture site was exposed and several fine adhesions connecting the tendon with the surrounding tissues were found and divided The last examination eight months after surgery revealed almost full range of movements of the interphalangeal joint of the right thumb (Figure 11)

Case 6

J R., a twenty two-year-old woman was admitted to us two hours after she injured her third right finger by a sewing machine In examination a slightly lacerated wound at the base of the finger with complete loss of active flexion were noted. The flexor tendon sheath was exposed and complete division of both flexors was revealed The ends of the sublimis were approximated by "U" suture and the ends of the deep flexor by "rasping suture It is to be emphasized that although no immobilization was applied the patient did not *exercise the injured finger* due to swelling and painful reaction dur ng the first two weeks One month later the movements were noted to be as follows distal interphalangeal joint 180–170 degrees, proximal interphalangeal joint 150–135 degrees. Two months after the injury in order to further improve the range of movements the suture site was re exposed and some adhesions around the flexor tendons were found and divided Active movements started on the next da Two weeks later the movements were noted to be nearly normal. The last examination two months after surgery revealed full range of movements of the injured finger (Figure 12)

Case 7

D R. a seventeen year old technician was admitted to us about five hours after injury Examination revealed a lacerated wound at the base of the volar surface of the fourth fing r and inability to flex the distal phalanx Under axillary block anaesthesia the wound was extended and the cut ends of the deep flexor identified They were anastomosed by grasping" suture. Active mo ements started on the next

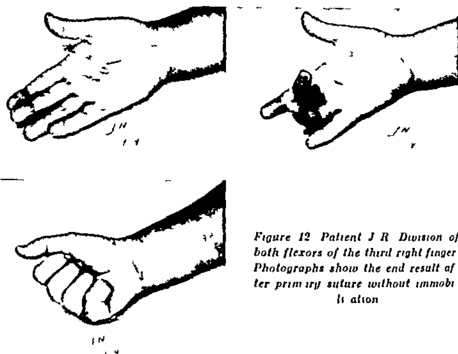


Figure 12 Patient J R Division of both flexors of the third right finger Photographs show the end result after primary suture without immobilization

day The case was followed two months after surgery and at the last examination showed a range of active movements of the distal interphalangeal joint between 130 and 180 degrees Unfortunately no photographs are available

COMMENTS

It has not been the purpose of the present study to investigate the importance and role of the anatomical appendices of the tendon (sheath vincula etc) in development of fibrosis This particular subject has been widely elaborated and reported in the past As stated previously our study has been limited to an attempt to examine and demonstrate the condition of an injured digital flexor tendon after primary end to end suture without immobilization

For the purposes of the investigation we have not been able to use any of the conventional methods of tendon suturing As it is known all of these methods are based on additional support by immobilization in order to keep the sutured tendon ends in contact We tried at the beginning of our experiments the well known Bunnell s figure eight suture This technique when applied in a non immobilized tendon invariably causes longitudinal separation of the tendon fibrils and retraction of its proximal end (Figure 13) As noted by Lindsay et al



Figure 13 Roentgenographic appearance of the regular Bunnell's figure eight suture (A) When not immobilized this suture allows longitudinal separation of the proximal fragment and its retraction into the palm (B)

(1960) even a plaster cast does not appear to be a completely effective means for avoiding a gap between the sutured tendon ends They found gaps occupied by *massive fibrotic formation in some of their* cases in spite of immobilization We have also seen very similar results using some kinds of internal fixation such as suture at a distance or blocking pins Obviously the muscular activity of the immobilized tendon is strong enough to split the fibres under the pin or wire weakening the fixation and causing either partial or complete disruption of the sutured ends With the suture proposed an attempt has been made to withstand the tendency for longitudinal separation As it is almost intratendinous this suture has been observed to cause if intact only a mild foreign body reaction

The first observation we made in our experiments was the relatively high incidence of ruptured sutures caused by rupture of the wire we used This shows the great difference between the tensile strength of the tendon and the tensile strength of the wire However whereas the tensile strength of the wire has a simple mechanical attitude the tensile strength of the intact and repaired tendons presents a number of biological problems As one of us pointed out on another occasion the tensile strength of foreign materials as well as the strength of their attachment to biological structures can be quite accurately measured by simple technical means (Kessler Niebauer & Howard 1967) As far as tendons are concerned many other factors have to be taken into consideration such as physiological action of the particular tendon size time after repair etc We did not elaborate on this particular point which is a subject for investigation by itself On the other hand we do believe that the obviously great difference between the tensile strength of the tendon and the wire is probably not very important in clinical application of the suture in which gradual and controlled movements replace the voluntary muscle contractions of the animals In fact technical details including type of suture and wire have been

of only secondary importance (cases 1 and 4) We realize that any type of suture which could withstand the normal muscle contractions and keep the tendon ends well approximated could have been used with the same or even better results Therefore the most impressive feature brought out by this investigation was the relationship in a significant proportion of instances between intact sutures and fibrous tissue proliferation It was clearly shown that intact sutures were characterized by highly reduced amount of adhesions whereas instances with partial or complete ruptures developed massive fibrotic reaction Moreover the mild adhesions in instances with intact sutures have even changed their nature they appeared as fine fibrotic bundles extended in the direction of gliding with adequate length to allow an almost normal excursion of the tendon

SUMMARY

A procedure of avoiding massive adhesions around primary repaired flexor tendons by immediate or early movements has been presented Experiments have shown that a strong anastomosis of an injured tendon without immobilization contributes to the development of mild *fibrotic reaction* It is also shown that early movements may change the nature of adhesions and preserve good physiological range of excursion

In order to obtain a strong and well adapted anastomosis a new suture technique that grasps the tendon substance with four knots has been described

REFERENCES

Ashley F L Stone R S Alonso Artiede M Syverud J M Edwards J Sloan R F & Mooney S A (1959) Experimental and clinical studies on the application of monomolecular cellulose filter tubes of create artificial tendon sheath in digits *Plast Reconst Surg* 23 526

Buchner H & Hofman E (1959) Experimentelle Untersuchungen zum Problem der Regeneration nach Sehnennahten *Arch orthop UnfallChir* 50 500

Bunnell S (1956) *Surgery of the hand* 3rd ed Lippincott Philadelphia p 574

Burman M S & Umansky M (1930) An experimental study of free periosteal transplants wrapped around tendon with a review of literature *J Bone Jt Surg* 12 579

Campbell Reid D A (1966) *Tendon injuries in clinical surgery* Butterworths London p 119

Farmer A W (1947) Experiences in the use of cellophane as an aid in tendon surgery *Plast Reconst Surg* 2 207

Gonsalez R. I (1949) Experimental tendon repair within the flexor tunnels use of polyethylene tubes for improvement of functional results in the dog *Surgery* 26 181

Cucukljian S A (1956) A new method for canalizing tendon sutures with vein grafts *Arch Surg* 73 1018

Kessler I., Niebauer J & Howard L. D (1967) Studies on the response of the medullary canal of long bones toward dacron D-119 *Plast reconst Surg* 39 307-310

Koch S L. (1946) Inflamed and injured tissues need rest *Surg Gynec Obstet* 82 749

Koth, D R & Sewell W H (1955) Freeze dried arteries used as tendon sheaths *Surg Gynec Obstet* 101 615

Lange M (1954) Kritische Stellungsnahme zur Behandlung der Beugesehnenverletzungen der Finger *Wiederherst Chir Traumat* 2 73

Lexer E. (1912) Verwethung der freien Sehnetransplantation *Arch klin Chir* 98 818

Lindsay W K & Thompson H G (1960) Digital flexor tendons an experimental study part 1 *Brit J plast Surg* 12 289

Lindsay W K. Thompson H G & Walker F G (1960) Digital flexor tendons the significance of a gap occurring at the line of suture part 2 *Brit J Plast Surg* 13 1

Littler J W (1959) The severed flexor tendon. *Surg Clin N Amer* 32 435

McCash Ch M (1961) The immediate repair of flexor tendons *Brit J plast Surg* 14, 53

McKee G K (1945) Metal anastomosis tubes in tendon suture *Lancet* 1 659

Murray G (1960) A method of tendon repair *Amer J Surg* 99 334

Potenza A D (1962) Tendon healing within the digital sheath in the dog An experimental study *J Bone Jt Surg* 44-A 49

Rank, B K & Wakefield, A R. (1960) *Surgery of repair as applied to hand injuries* Livingstone Edinburgh and London p 119

Skoog T & Persson B H (19 4) *An experimental study of the early healing of tendons Plast reconst Surg* 13 384

Verdan C. E. (1960) Primary repair of flexor tendons. *J Bone Jt Surg* 42 A 647

Weckesser E C. Shaw B W Spears G N & Shea F C. (1949) A comparative study of various substances for the prevention of adhesions about tendons *Surgery* 23 361

Young R. E. S & Harmon J M (1960) Repair of tendon injuries of the hand *Ann Surg* 151 562

of only secondary importance (cases 1 and 4) We realize that any type of suture which could withstand the normal muscle contractions and keep the tendon ends well approximated could have been used with the same or even better results Therefore the most impressive feature brought out by this investigation was the relationship in a significant proportion of instances between intact sutures and fibrous tissue proliferation It was clearly shown that intact sutures were characterized by highly reduced amount of adhesions whereas in stances with partial or complete ruptures developed massive fibrotic reaction Moreover the mild adhesions in instances with intact sutures have even changed their nature they appeared as fine fibrotic bundles extended in the direction of gliding with adequate length to allow an almost normal excursion of the tendon

SUMMARY

A procedure of avoiding massive adhesions around primary repaired flexor tendons by immediate or early movements has been presented Experiments have shown that a strong anastomosis of an injured tendon without immobilization contributes to the development of mild fibrotic reaction It is also shown that early movements may change the nature of adhesions and preserve good physiological range of excursion

In order to obtain a strong and well adapted anastomosis a new suture technique that grasps the tendon substance with four knots has been described

REFERENCES

Ashley F L Stone R S Alonso Artiede M Syverud J M Edwards J Sloan R F & Mooney S A (1959) Experimental and clinical studies on the application of monomolecular cellulose filter tubes of create artificial tendon sheath in digits *Plast Reconst Surg* 23 526

Buchner H & Hofman E (1959) Experimentelle Untersuchungen zum Problem der Regeneration nach Sehnennahten *Arch orthop UnfallChir* 50 500

Bunnell S (1956) *Surgery of the hand* 3rd ed Lippincott Philadelphia p 524

Burman M S & Umansky M (1930) An experimental study of free periosteal transplants wrapped around tendon with a review of literature *J Bone Jt Surg* 12 579

Campbell Reid D A (1966) *Tendon injuries in clinical surgery* Butterworths London p 119

Farmer A W (1947) Experiences in the use of cellophane as an aid in tendon surgery *Plast Reconst Surg* 2 207

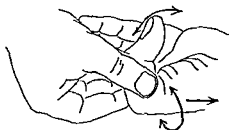


Figure 1 Proximal pressure during rotation clearly demonstrates the rotation pain The tip of the thumb is an indicator of the extent of rotation

On examination there is tenderness over the joint which is often dislocated It is important to test passive rotation Pain on rotation and painful crepitations are the most common signs Rotation is also limited This test can be performed in a very simple way as shown in Figure 1 With maximal flexion of the metacarpophalangeal joint the collateral ligaments of this joint are under tension and the proximal phalanx can be used as a handle The tip of the thumb is then an indicator of the extent of rotation Proximal pressure during rotation clearly demonstrates the rotation pain

Radiographically the signs of arthritis are seen including decreased joint space osteophytes sometimes loose bodies in the joint and dislocation of the first metacarpal base There seems to be no correlation between the radiographic findings and the patient s complaints

TREATMENT

Different treatments have been suggested for instance heat short wave therapy immobilization X ray local injections of steroids etc The effects of these are doubtful Surgical treatment is to be preferred Excision of trapezium is usually recommended in the literature The method appears to give good results for pain but there is some loss of power In addition there is great danger in using the recommended dorsal incision because of the risk of damage to the radial nerve and thus troublesome neuromas in the scar For instance in a series of cases with dorsal incisions Murley (1960) found persistent complaints due to neuromas in 65 per cent

It would seem that arthrodesis is the method of choice if reduction of strength of the hand is to be avoided

At the Department of Bone and Joint Surgery University of Gothen

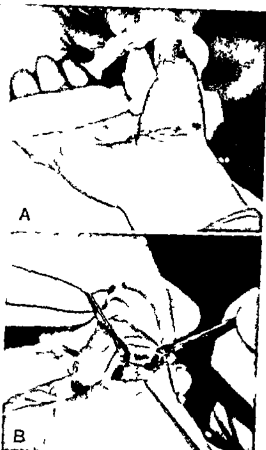


Figure 2 A The incision follows the volar crease at the base of the thumb B After cutting the proximal insertion of the thenar muscles and dissecting the muscles free from the carpus in distal direction the first carpo metacarpal joint is well exposed

burg such cases have been treated by arthrodesis using a method developed by Moberg

TECHNIQUE

A volar incision is made following the crease at the base of the thumb (Figure 2A) The proximal insertion of the thenar muscles is cut and without injuring the muscles they are dissected free from the carpus in a distal direction The first carpo metacarpal joint is thus well exposed (Figure 2B) The joint surfaces of the first metacarpal and trapezium are resected The surfaces are fitted to each other with the thumb in the position of function and stabilized by fixation with 2 mm thick steel wire This wire is drawn through holes in trapezium and the first metacarpal and then twisted (Figure 3) The twisted end is buried in the cortical bone of the metacarpal The thenar muscles are then

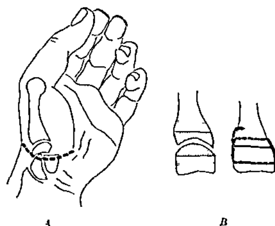


Figure 3 A Skeleton drawing showing the anatomical correlation between the skin incision (dotted line) and the first carpo metacarpal joint B After resection of the joint surfaces a 2 mm thick steel wire is drawn through holes in the metacarpal and trapezium and twisted This fixation gives a good stability as well as compression in the arthrodesis The twisted end of the wire is buried in the cortical of the metacarpal

sutured back in place and the skin is closed with interrupted steel wire sutures Immobilization in plaster of Paris for 6–8 weeks

FOLLOW UP

During the years 1959–1964 22 patients have been operated on Nineteen of these have been traced and examined of whom 3 have been operated bilaterally There were 17 women and 2 men between 36 and 74 years of age with an average of 58 years Prior to operation half of the patients had received various treatments with only temporary effects The patients were followed up 1–5½ years after operation

Incapacity for work after operation varied from 2½–6 months on the average about 4 months When fit for work all the patients went back to their previous occupations even if these were heavy

RESULTS

Of the patients 4 were functionally perfect Fourteen had no pain at rest but slight pain on grasping some clumsiness etc and one patient was unimproved Thus 18 of the 19 patients were free of pain at rest



Figure 4 Osteoarthritis in the first carpo metacarpal joint before treatment (left) and after a healed arthrodesis (right)

In spite of this the radiographs showed bony healing in only 50 per cent of the cases No correlation was found between the painlessness and bony healing of the arthrodesis

In one patient the results were bad She was operated on twice The second operation was made because of persistent complaints and an unhealed arthrodesis This second arthrodesis healed well but the patient s complaints were the same Radiographically however there were signs of other joint destruction in her wrist especially in the trapezio scaphoid joint This joints to the importance of checking this joint before attempting an arthrodesis in the first carpometacarpal joint

There were no preoperative figures of the gross power so the hand grip in those cases operated unilaterally was compared with the other hand assuming that the weaker hand was operated on This evaluation showed no difference in gross power between the two sides

There was very little decrease in opposition of the thumb On the other hand there was a decrease in the adduction of the thumb but none of the patients had any complaints Even when the arthrodesis had healed there was a certain amount of mobility at the base of the metacarpal This mobility is in the joint between trapezium and the carpus and may improve postoperatively

The incision described has in all cases healed well with a hardly visible scar and with no neuromas

SUMMARY

A new operative technique is described for arthrodesis of the first carpo metacarpal joint together with a follow up of 19 operated patients In 18 of 19 cases the patients became free of pain in spite of the fact that only 50 per cent of the arthrodeses healed with bony union

The operation did not decrease the power of the grip

Before attempting an arthrodesis of the first carpometacarpal joint it is important to check the mobility of the metacarpo phalangeal and the interphalangeal joints of the thumb and also for the absence of *osteoarthritis in the trapezio scaphoid joint*

REFERENCES

Aune S (1955) Osteo-arthritis in the first carpo metacarpal joint *Acta chir Scand* 109 449–456

Forestier J (1937) L osteo arthrite seche trapezo metacarpienne *Presse Med* 45 315–317

Gervis W H (1948) *Excision of the trapezium for osteo arthritis of the trapezio* metacarpal joint. *Postgr med J* 24, 262–264

Gervis W H (1949) Excision of the trapezium for osteoarthritis of the trapezio metacarpal joint. *J Bone Jt Surg* 31 *B* 537–539

Goldner J L & Clippinger F W (1958) Excision of the multangular bone as an adjunct to mobilization of the thumb *J Bone Jt Surg* 41 A 609–625

Gylling B (1960) Surgical treatment of painful arthrosis in the carpo metacarpal joint of the thumb *Op med* 5 350–352

Lassarre Ch., Pauzat, D & Derennes R. (1949) Osteoarthritis of the trapezio meta *carpal joint. J Bone Jt Surg* 31 B 534–536

Michele A A Skinner H. L. & Krueger F J (1950) Repair and stabilization of the first carpometacarpal joint *Amer J Surg* 79 348–349

Murley A H (1960) Excision of the trapezium in osteoarthritis of the first carpo metacarpal joint. *J Bone Jt Surg* 42 B 502–507

Müller G M (1949) Arthrodesis of the trapezio metacarpal joint for osteoarthritis. *J Bone Jt Surg* 31 B 540–542

Acta orthop Scandinav 40 608–613 1969

Department of Orthopaedic Surgery (Head T Hierton M D)
and the Department of Diagnostic Radiology (Former Head F Knutsson M D)
University Hospital Uppsala Sweden

EVALUATION OF THE RELIABILITY OF RADIOLOGICAL METHODS FOR REGISTRATION OF SCOLIOSIS

J A Sevastikoglou & E Bergquist

Received iii 68

Every orthopaedic surgeon dealing with scoliotic children faces the problem of estimating increases of the spinal curvatures in his patients Accurate records including photographs of the patient measurements of the total body height and the length of the trunk do not permit evaluation of minor progress of the spinal deformity which might be of importance for either prognostic or therapeutic reasons In such cases the radiologist is called to give the desired information by numerical measurements of the spinal curves on X rays

There are two main methods commonly used for measurement of the scoliotic angulation of the spine on X ray films The first method described by Ferguson (1945) and called by Lusskin (1962) the middle of curve method is based on measurements of the angle formed by two lines one drawn through the geometrical centres of the apical vertebra and the top vertebra of the curve and one through the centres of the apical vertebra and the lowest vertebra of the curve The second method described first by Lippman (1935) and popularized later by Cobb (1948) has been called the end of curve method by Lusskin This method is based on measurement of the angle formed by the intersection of the perpendiculars of one line drawn through the superior surface of the top vertebra and one drawn through the inferior surface of the lowest vertebra of the scoliotic curve Measurements performed by either of these methods from time to time are considered to give reliable information regarding the development of the spinal deformity In many cases however it is doubtful whether minor changes recorded by measurements on the X ray films of consecutive examinations of the same patient are significant and the

question arises consequently as to the margins of error of these methods It is commonly said that minor differences of comparative numerical evaluations on X ray films can be due to errors of the projection depending among other things on changes of the position of the X rayed object or on centring variations of the tube between two examinations In such cases the reliability of these estimations is unknown

The present study has been undertaken by the authors in order to evaluate the reliability of the commonly used radiological methods for registration of scoliosis

MATERIAL AND METHOD

The head the spine, and the pelvis of a scoliotic skeleton were assembled and fixed by help of a plexiglass rod passed through the spinal canal and strips of scotch tape In this way good stability of the spine was achieved and the specimen was then immobilized on a plexiglass plate by strips of scotch tape The specimen could be moved and rotated at will without interfering with the scoliotic angulation itself *The convexity of the scoliosis was to the right.* The spine was X rayed several times by moving the tube or rotating the specimen in various directions and to various degrees for each exposure as is demonstrated in Table 1 After loosening the spine from the plexiglass plate it was re immobilized in the same way as above and new exposures were taken with the same variations of rotation of the specimen and movements of the tube The distance between the tube and the film was always 150 cm.

The scoliotic angulation was measured on each X ray film by help of a goniometer and according to both Ferguson s and Cobb s method Measurements were made by each author separately and the mean value of the two estimations $\frac{(A+B)}{2}$ was used

The combination of the centring of the tube and the degree of rotation during the various exposures of the two specimens as well as the results of the measurements are demonstrated in the following table

RESULTS AND DISCUSSION

The measurements performed under the described conditions indicate that regardless of the method used for the numerical evaluation of a scoliotic angulation on X ray films minor deviations of the values occur by rotation of the spine or by movements of the tube although the scoliotic deformity remains unchanged Thus as is shown in Table 1 the absolute differences in measurements between the control and the examined exposures had a mean value 1 1? ± 0 98 for the Ferguson and 2 06 ± 1 09 for the Cobb method in the first specimen and

Table 1 Material

Expo sure no	Rotation of the spine	Centring of the X ray tube	Speci		
			F		
			$\frac{A+B}{2}$	d	C d
Control	Neutral	On the spinal process of the apical vertebra	53	—	—
1	5 at right	On the spinal process of the apical vertebra	54	+1 0	1 88
2	10° at right	On the spinal process of the apical vertebra	56 5	+3 5	6 60
3	10 at left	On the spinal process of the apical vertebra	48	—5 0	9 43
4	5 at left	On the spinal process of the apical vertebra	52 5	—0 5	0 94
5	Neutral	5 cm below the sp proc of the ap vert	52 5	—0 5	0 94
6	Neutral	5 cm above the sp proc. of the ap vert	50 5	—2 5	4 1
7	Neutral	5 cm at right of the sp proc. of the ap vert	55 0	+2 0	3 47
8	Neutral	5 cm at left of the sp proc of the ap vert.	51 0	—2 0	3 77
9	10 at right	5 cm below the sp proc of the ap vert.	52 5	—0 5	0 94
10	10 at right	5 cm above the sp proc of the ap vert	50 5	—2 5	4 41
11	10 at right	5 cm at right of the sp proc of the ap vert	50 0	—3 0	5 66
12	10 at right	5 cm at left of the sp proc of the ap vert	51 0	—2 0	3 47
13	10 at left	5 cm at left of the sp proc of the ap vert	58 0	+5 0	9 43
14	10 at left	5 cm at right of the sp proc of the ap vert	60 0	+7 0	13 0
15	10 at left	5 cm below the sp proc of the ap vert	59 5	+6 5	12 67
16	10 at left	5 cm above the sp proc of the ap vert	60 5	+7 5	14 15
d			—	1 15	6 04
sy			—	±0 93	±1 11

$\frac{A+B}{2}$ = Mean value of the individual measurements of the two authors
F = Measurement by Ferguson s method
C = Measurement by Cobb s method

0 60 ± 0 21 and 0 98 ± 0 31 respectively for the second The percentage differences were 6 04 ± 1 11 and 6 40 ± 1 05 in the first specimen and 1 28 ± 0 43 and 1 82 ± 0 59 in the second specimen

The differences between the measurements performed by each of the authors (A–B) ranged between —5° and +3 for the Ferguson method and between —11 and +9 for the Cobb The mean difference between all measurements performed by each author i e the error of the measurements was for the Ferguson method 1 82 ± 0 21 and for the Cobb method 3 12 ± 0 48

Cobb s method gave consistently higher values than Ferguson s method in all exposures the difference ranged between 1 and 16° mean value 7 84 ± 0 51 i e 8 47 ± 0 73 in the first and 7 20 ± 0 70 in the second specimen

and results

men I				Specimen II						
C			C-F	F			C			C-F
$\frac{A+B}{2}$	d	% d		$\frac{A+B}{2}$	d	% d	$\frac{A+B}{2}$	d	% d	
60.5	—	—	6.5	59.5	—	—	67.5	—	—	8.0
61.0	+0.5	0.87	7.0	58.5	−1.0	1.68	66.5	−1.0	1.48	8.0
61.5	+1.0	1.65	5.0	58.5	−1.0	1.68	66.5	−1.0	1.48	8.0
54.5	−6.0	9.91	6.5	59.75	+0.25	0.42	66.25	−1.25	1.85	7.5
59.5	−1.0	1.65	7.0	60.00	+0.5	0.84	68.5	+1.0	1.48	8.5
61.5	+1.0	1.65	9.0	58.5	−1.0	1.68	66.0	−1.5	2.22	7.5
66.5	+6.0	9.91	16.0	59.5	0.0	0.00	67.0	+0.5	0.74	7.5
63.0	+2.5	4.13	8.0	59.0	−0.5	0.84	66.5	−1.0	1.48	7.5
66.5	+6.0	9.91	15.5	58.0	−1.5	2.52	66.5	−1.0	1.48	8.5
62.5	+2.5	4.13	10.5	57.0	−2.5	4.20	65.0	−2.5	3.70	8.0
58.0	−2.5	4.13	7.5	58.5	−1.0	1.68	65.5	−2.0	2.96	7.0
58.5	−2.0	3.30	8.5	58.0	−1.5	2.52	67.0	−0.5	0.74	9.0
56.5	−3.5	5.78	5.5	59.5	0.0	0.00	65.5	−2.0	2.96	6.0
66.0	+5.5	9.09	8.0	59.5	0.0	0.00	63.5	−4.0	5.92	4.0
67.5	+7.0	11.59	7.5	58.5	−1.0	1.68	67.5	0.0	0.00	9.0
67.5	+7.0	11.57	8.0	59.5	0.0	0.00	67.75	+0.25	0.37	8.2
68.5	+8.0	13.22	8.0	60.0	+0.5	0.84	67.75	+0.25	0.37	8.25
—	2.06	6.40	8.47	—	0.60	1.28	—	0.98	1.82	7.20
—	±1.09	±1.05	±0.73	—	±0.21	±0.43	—	±0.31	±0.59	±0.70

d = Difference in degrees from neutral.
% d = Percentage difference from neutral
$\bar{d}$ = Mean difference.
= Standard deviation of the mean

Generally speaking the registered differences of the performed measurements were somewhat higher for the first than for the second specimen The absolute and the percentage differences between the control and the 16 exposures in each specimen were almost of the same degree of magnitude for both methods of measurement

The reported results indicate further that rotation of the spine alone by 5 to 10 in either direction without movement of the tube (exposures 1–4) and movement of the tube by 5 cm in either direction without rotation of the spine (exposures 5–8) as well as combined rotation of the spine and movement of the tube (exposures 9–12 and 13–16) results in differences in the measurements of the scoliotic deformity which however hardly surpass the margins of error of

the measurements at least when the values obtained from both specimens are considered together

George & Rippstein (1961) performed measurements of the spinal deformity by Ferguson's and Cobb's methods on the X-ray films of 25 scoliotic patients with a total of 27 curves before and after correction of the scoliosis. The mean difference between measurements performed by Cobb's and Ferguson's method was 13 29 before correction. The authors found further that Cobb's method showed a consistently higher percentage of correction than Ferguson's method did. The mean percentage difference between the two methods was 16 per cent. The authors maintained that the margin of error in the Ferguson method is minimum and that by this method exaggeration of the curve before correction and exaggeration of the amount of correction after treatment are completely excluded.

Lusskin (1962) by comparing Ferguson's and Cobb's method on 11 scoliotic patients found a mean difference of 14 6 between the results obtained by each of the methods.

The results of the present study are in agreement with the earlier observations as to the larger values obtained by measuring scoliotic curves on X-ray films by Cobb's than by Ferguson's method. However appreciable differences neither in absolute nor in percentage values do not exist between measurements performed by the two methods.

SUMMARY

An evaluation of the results obtained by consecutive measurements on X-ray films of an unchanged scoliotic deformity of the spine by Ferguson's and Cobb's methods has been done.

It was found that minor rotations of the spine as well as movements of the X-ray tube or a combination of both do not influence the results of reading in an appreciable degree whether Ferguson's or Cobb's method is used. The margins of error of the numerical measurements of the scoliotic curve on X-ray films are however relatively small i.e. 1 82 ± 0 21 for Ferguson's and 3 12 ± 0 48 for Cobb's method.

Measurements performed by Cobb's method gave consistently higher values than those performed by Ferguson's method, the differences ranging between 4 and 16, mean values 7 84 ± 0 51. There were however no appreciable differences between measurements performed by the two methods.

REFERENCES

Cobb J R (1948) *Amer Acad Orthop Surg* 5 ? 1 Ann Arbor J W Edwards
Ferguson A B (1945) *Roentgen diagnosis of the extremities and spine* N Y Paul Hoeber Inc.
George K & Rippstein J (1961) *J Bone Jt Surg* 43 A 809
Lippman Cited by Cobb
Lusskin R. (1962) *Clin Orthop* 23 ?32

Acta orthop Scandinav 40 614-623 1969

From the Department of Orthopaedics Norrbacka Institutet (Head Prof S Friberg) and the Department of Clinical Physiology Serafimerlasarettet Karolinska Institutet (Head Assoc Prof B Pernow) Stockholm Sweden

THE COLD SCIATIC LEG

ANDERS HAKELIUS ULF NILSONNE BENGT PERNOW
& STAFFAN ZETTERQUIST

Received 1 ii 68

Pain is the predominant symptom in sciatica which may also involve paresthesia and/or pareses Less attention has been paid to the sensation of cold that is sometimes experienced in the lower leg and foot on the affected side Although the patient may wear a thick extra sock to counter this discomfort it is seldom reported spontaneously When questioned on the subject however nearly all patients state that they suffer from cold in the lower leg and foot on the affected side

The peripheral cold is mentioned only occasionally and in passing in the voluminous literature on the sciatic syndrome No detailed analysis of this symptom has been published *Berquet* (1963) admittedly mentioned in a short report that a difference between the sciatic and the healthy leg was found in measurements of the skin temperature though not at oscillography but no data were published and the finding has not been followed up

The aims of the present study were

1 To investigate whether there is an objectively measurable temperature difference between the sciatic and the healthy leg in subjects with symptoms of pressure on lumbar nerve roots

2 To investigate whether this difference between the legs changes after the pressure on the nerve roots has been relieved by conservative or surgical measures

---

Supported by grants from Skandia Insurance Company Stockholm Sweden which is greatfully acknowledged

Table 1 Clinical data in 28 patients with sciatica.

Case No	Sex	Age	Duration of sciatic symptoms	Nerve root affected according to Neurol findings	Myelography	Op findings
1	♀	43	3 months	LV + SI	SI	SI
2	♂	52	6	SI	SI	SI
3	♂	37	6	LV	LV	LV
4	♂	42	7 months	SI	SI	SI
5	♀	25	9 months	No neurol findings	Neg. myelography	No disc herniation
6	♀	33	8 months	LV	LV	LV
7	♂	21	4	No neurol findings	SI	SI
8	♀	34	13	No neurol findings	LV	LV
9	♀	33	3 weeks	SI	SI	SI
10	♀	45	2 months	SI	SI	SI
11	♂	34	5	No neurol findings	SI	SI
12	♂	39	6 months	No neurol findings	LV	LV
13	♂	29	1 months	LV + SI	LV	LV
14	♀	35	2 weeks	SI	SI	SI
15	♀	37	13 months	No neurol findings	Neg myelography	SI
16	♀	51	2 months	LV + SI	SI	SI
17	♀	33	2 months	SI	SI	SI
18	♂	22	6	SI	SI	SI
19	♀	38	2 months	LIV + LV + SI	Total block LV	SI
20	♀	47	12	LV	LV (?)	LV
21	♀	36	3 months	SI	SI	SI
22	♂	32	6 months	LV	LV (?)	No operation
23	♂	19	5	LV	LV	No operation
24	♂	49	14 months	LIV + SI	LV	No operation
25	♀	38	24	SI	SI	No operation
26	♂	21	12 months	LIV + LV	Neg myelography	No operation
27	♂	39	2 months	LV	SI	No operation
28	♂	50	2	No neurol findings	Myelography *not performed*	No operation

MATERIAL

The study was made on 28 patients (see Table 1) 14 males and 14 females mean age 35.5 years (range 19–52 years) Only persons below 55 years of age were included, in an attempt to avoid cases with obliterative vascular disease. No clinical signs of stenotic vascular disease were detected in any of the subjects. All the patients had typical, unilateral sciatics with symptoms that had lasted from a fortnight up to two years

The first part of the examination concerned the patients skin temperature and the arterial and venous blood flow at rest in both the lower extremities (see Methods below) In all but one case the clinical diagnosis was then verified roentgenologically by lumbar myelography with a positive contrast medium (Perabrodil®) Twenty one patients were treated surgically twenty of them with resection of a herniated disc in six of these cases the herniation lay between L IV and L V in fourteen between L V and S I In the remaining operated case there was no disc herniation Seven patients received conservative treatment with physiotherapy and/or a brace The examination of the circulation was repeated at an average of 9 months after the end of treatment in fourteen of the operated cases and four of those treated conservatively

PROCEDURE AND METHODS

The examinations were conducted with the subject supine and the legs bare Before the examination the subject spent 30 minutes resting in order to adapt to the room temperature which was 18–22 C

The *skin temperature* was measured with thermocouples taped to the skin and registered on a mirror galvanometer (TE3 Ellab Denmark) Bilateral measurements were made on the following points (*a*) underneath the big toe (*b*) the outside of *the foot on a level with the head of the fifth metatarsal (c) the sole of the foot* 2 cm proximal of the third toe (*d*) the dorsum of the foot 2 cm proximal of the third toe (*e*) 5 cm proximal of the medial malleolus and (*f*) 20 cm proximal of the lateral malleolus

The measurements were performed before and during sympathicolysis (*Lewis & Pickering* 1931) elicited by heating the trunk with a thermostatic heating box set at 40 C Before this heat treatment the patient received 50 ml of a lytic cocktail containing 50 per cent alcohol In two cases the skin temperature was also measured 20 minutes after the posterior tibial nerve had been blocked with 5 ml 1 per cent Xylocain®

Digital plethysmography was performed according to *Lund* (1949) after indirect heating for 40 minutes Arterial toe pulse curves were obtained via a closely fitting plastic hood and piezoelectric pressure receptor on the second toe coupled to a *Mingograph (Elema Schonander) The average propagation time* inclination time and amplitude were calculated bilaterally from three consecutive curves

Venous occlusion plethysmography was undertaken in four patients using a modified Dohn plethysmograph (*Graf & Westersten* 1959) The resting circulation was determined in a segment of the maximal part of the calf on either leg by calculating the mean of five consecutive recordings

RESULTS

A *Preoperative Studies*

1 *Skin temperature* (Table 2) The basal skin temperature was generally lower on the affected leg than on the contralateral one The *measured difference was significant over the medial malleolus* and the sole of the foot ($p < 0\,001–0\,01$) The differences obtained during

Table 2 Skin temperature before and during indirect (body) heating in the acute phase of sciatica in 28 patients A indicates the affected leg and C the control leg

Time after body heating in min	Leg	Skin area: Big toe			Fifth metatarsal			Sole of foot		
		Mean	SD	P	Mean	SD	P	Mean	SD	P
0	A	24.3	4.7	> 0.1	25.9	3.4	< 0.05	24.9	4.1	< 0.01
	C	24.9	4.8		26.6	3.1			4.0	
20	A	30.2	4.9	< 0.01	29.1	4.3	< 0.02	29.8	4.7	< 0.01
	C	31.3	4.5		30.1	4.1		30.8	4.3	
30	A	32.2	3.2	< 0.02	30.6	3.7	< 0.02	31.2	4.3	< 0.02
	C	32.9	2.8		31.4	3.5		32.2	3.4	
40	A	33.0	2.3	< 0.05	31.1	3.6	< 0.05	31.9	3.6	< 0.01
	C	33.5	1.6		31.7	3.4		32.9	2.5	

Time after body heating in min	Leg	Skin area: Dorsum of foot			Medial malleolus			Lateral side of calf		
		Mean	SD	P	Mean	SD	P	Mean	SD	P
0	A	26.9	3.5	< 0.05	29.8	2.0	< 0.001	31.5	1.3	< 0.02
	C	27.5	3.4		30.7	1.8		32.0	1.0	
20	A	29.8	3.8	< 0.01	30.4	1.7	< 0.01	31.1	1.2	> 0.2
	C	30.8	3.6		31.2	1.9		31.2	1.1	
30	A	31.6	3.2	< 0.05	31.0	1.6	< 0.001	30.9	1.0	> 0.2
	C	32.3	2.6		31.8	1.8		31.0	1.1	
40	A	32.4	2.5	< 0.01	31.6	1.4	< 0.01	30.9	1.0	> 0.2
	C	33.1	1.9		32.2	1.6		31.0	1.0	

The p values refer to the significance of the differences between paired observations.

indirect heating were still more pronounced being significant between the majority of the bilaterally identical measuring points within 20–30 minutes

The posterior tibial nerve was blocked on the affected side in two cases once indirect heating had produced an optimal effect One of these cases is illustrated in Figure 1 which shows the very marked differences between the two legs after indirect heating and the almost complete elimination of these after the blockade

It was found that the patients with an S I syndrome had greater temperature differences on the average between the affected and the

The first part of the examination concerned the patients skin temperature and the arterial and venous blood flow at rest in both the lower extremities (see Methods below) In all but one case the clinical diagnosis was then verified roentgenological ly by lumbar myelography with a positive contrast medium (Perabrodil®) Twenty one patients were treated surgically twenty of them with *resection of a herniated disc* in six of these cases the herniation lay between L IV and L V in fourteen be tween L V and S I In the remaining operated case there was no disc herniation Seven patients received conservative treatment with physiotherapy and/or a brace. The examination of the circulation was repeated at an average of 9 months after the end of treatment in fourteen of the operated cases and four of those treated con servatively

PROCEDURE AND METHODS

The examinations were conducted with the subject supine and the legs bare Before the examination the subject spent 30 minutes resting in order to adapt to the room temperature which was 18–2? C

The *skin temperature* was measured with thermocouples taped to the skin and registered on a mirror galvanometer (TE3 Ellab Denmark) Bilateral measurements were made on the following points (*a*) underneath the big toe (*b*) the outside of the foot on a level with the head of the fifth metatarsal (*c*) the sole of the foot 2 cm proximal of the third toe (*d*) the dorsum of the foot 2 cm proximal of the third toe (*e*) 5 cm proximal of the medial malleolus and (*f*) 20 cm proximal of the lateral malleolus

The measurements were performed before and during sympathicolysis (*Lewis & Pickering* 1931) elicited by heating the trunk with a thermostatic heating box set at 40 C. Before this heat treatment, the patient received 50 ml of a lytic cocktail containing 50 per cent alcohol In two cases the skin temperature was also measured 20 minutes after the posterior tibial nerve had been blocked with 5 ml 1 per cent Xylocain®

Digital plethysmography was performed according to *Lund* (1949) after indirect heating for 40 minutes Arterial toe pulse curves were obtained via a closely fitting plastic hood and piezoelectric pressure receptor on the second toe coupled to a Mingograph (Elema Schonander) The average propagation time inclination time and amplitude were calculated bilaterally from three consecutive curves

Venous occlusion plethysmography was undertaken in four patients using a modified Dohn plethysmograph (*Graf & Westersten* 1959) The resting circulation was determined in a segment of the maximal part of the calf on either leg by calculating the mean of five consecutive recordings

RESULTS

A Preoperative Studies

1 *Skin temperature* (Table 2) The basal skin temperature was generally lower on the affected leg than on the contralateral one The measured difference was significant over the medial malleolus and the sole of the foot ($p < 0.001$–0.01) The differences obtained during

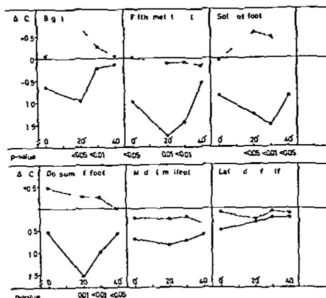


Figure 2 Mean difference in skin temperature between the affected and the healthy leg in 14 patients before (———) and after (– – – – –) excision of a prolapsed disc The difference between the legs was calculated separately for each of four sets of measurements from six different points during indirect body heating The values of p indicate the statistical effect of the operation on these differences

other segments This difference was not significant owing to the small number of cases

C *Patients Receiving Conservative Treatment*

The changes in skin temperature after conservative treatment of the sciatica were of the same magnitude as in the surgical cases There were too few patients for a statistical analysis of this group (4 cases)

DISCUSSION

The comparatively low skin temperatures particularly in the distal part of the leg in acute sciatica indicate a reduced skin blood flow The simultaneous finding of normal arterial toe pulse curves in these cases rules out obliterative arterial disease as a cause of the peripheral circulatory disturbance Moreover the absence of any effect on the calf blood flow at rest points to a selective disturbance of the skin circulation On the other hand the fact that peripheral nerve block

in the affected leg entirely eliminates the difference in skin temperature between this and the contralateral leg in unilateral sciatica (Figure 1) suggests that the difference is conditioned by a regionally enhanced vasoconstrictor activity This is also indicated by the slow appearance and incomplete nature of the effect of indirect (body) heating on the skin temperature in the affected leg Normally this procedure which diminishes the sympathetic vasoconstrictor tone causes the skin blood flow and hence the skin temperature to rise rapidly to an optimal level (*Lewis & Pickering* 1931 *Roddie, Shepherd & Whelan* 1956)

The sympathetic nervous system is chiefly an afferent system Its preganglionic fibres are said to emerge from the spinal cord via the ventral nerve roots in the segment T I L (*Brain* 1962) T I L II (*Broman* 1934 *White & Smithwick* 1948 *Bonica* 1954) or T I L III (*MacDonald & Chusid* 1952) There would thus appear to be some uncertainty as to which is the most caudal segment containing elements from the sympathetic nervous system There can be no doubt on the other hand that the nerve roots L IV L V and S I which are the ones commonly engaged in rupture of a lumbar disc do not contain efferent sympathetic nerve fibres The parasympathetic nervous system which probably has no influence over vascular tonus in the leg is incorporated in the nerve roots S II S IV *i e* below the levels involved in rupture of a lumbar disc It follows that the augmented vasoconstrictor activity in the acute phase of sciatica cannot be ascribed to a mechanical effect from a ruptured disc on efferent pathways in the autonomic nervous system

There are however several observations to the effect that increased activity in the sympathetic vasoconstrictor tone can be reflexly elicited by pain resulting in a diffuse efferent outflow *Adams Ray & Pernow* (1949) demonstrated for instance that an inflamed area is frequently surrounded by a pale zone and that this pallor syndrome can be eliminated by sympathetic block Pain in visceral organs also elicits vasoconstriction in the corresponding dermatome as a result of a reflexly increased flow of impulses from vasoconstrictor fibres (*Wernoe* 1920 *Adams Ray* 1953) The pains in the leg elicited by compression of the nerve root in the present cases might similarly give rise to reflexly increased vasoconstrictor tone and hence a reduced skin circulation particularly in the distal parts of the leg where the autonomic innervation is extensive Such a hypothesis would also explain why the effect on the skin temperature apparently did not coincide with the

dermatomes for the affected nerve roots The theory is also supported by the finding that the low skin temperature seems to have normalized with the cessation of the pain regardless of whether this occurred after conservative treatment or after surgical correction of the pressure on the nerve root

The results explain why sciatic patients frequently experience peripheral cold in the affected leg This phenomenon does not seem to have been verified objectively before nor has it been analyzed in relation to the effect of the treatment given The results also suggest that measurements of skin temperature may be valuable for an objective assessment of *clinically indefinite cases of sciatica*

SUMMARY

The skin temperature of the foot and lower leg was measured bilaterally in 28 patients with typical unilateral sciatica and symptoms that had lasted from a fortnight up to two years The examination was conducted before and after surgical or conservative treatment

The basal skin temperature on the medial malleolus and the sole of the foot on the affected side was significantly lower compared with the corresponding contralateral points The difference was still more marked after indirect body heating for 20–30 minutes The difference in temperature which was greater in patients with an S I syndrome than in those with an L V syndrome was eliminated after posterior tibial nerve block The basal calf blood flow did not differ between the two legs

After the surgical or conservative treatment when the patients were *free from symptoms* the *difference in skin temperature between the legs* was substantially smaller This applies both to the basal temperatures and to the temperatures during indirect heating The improvement was most marked in cases with an S I syndrome

The results indicate that measurements of skin temperature are of practical value for an objective assessment of clinically indefinite cases of sciatica

RESUME

La temperature de la peau du pied et de la jambe inferieure a ete mesuree bilateralement sur 28 patients souffrant d une sciatique typiquement unilaterale et dont les symptomes s etaient etendus sur une periode de 2 semaines a 2 ans

in the affected leg entirely eliminates the difference in skin temperature between this and the contralateral leg in unilateral sciatica (Figure 1) suggests that the difference is conditioned by a regionally enhanced vasoconstrictor activity This is also indicated by the slow appearance and incomplete nature of the effect of indirect (body) heating on the skin temperature in the affected leg Normally this procedure which diminishes the sympathetic vasoconstrictor tone causes the skin blood flow and hence the skin temperature to rise rapidly to an optimal level (*Lewis & Pickering* 1931 *Roddie, Shepherd & Whelan* 1956)

The sympathetic nervous system is chiefly an efferent system Its preganglionic fibres are said to emerge from the spinal cord via the ventral nerve roots in the segment T I L (*Brain* 1962) T I L II (*Broman* 1934 *White & Smithwick* 1948 *Bonica* 1954) or T I L III (*MacDonald & Chusid* 1952) There would thus appear to be some uncertainty as to which is the most caudal segment containing elements from the sympathetic nervous system There can be no doubt on the other hand that the nerve roots L IV L V and S I which are the ones commonly engaged in rupture of a lumbar disc do not contain efferent sympathetic nerve fibres The parasympathetic nervous system which probably has no influence over vascular tonus in the leg is incorporated in the nerve roots S II S IV *i e* below the levels involved in rupture of a lumbar disc It follows that the augmented vasoconstrictor activity in the acute phase of sciatica cannot be ascribed to a mechanical effect from a ruptured disc on efferent pathways in the autonomic nervous system

There are however several observations to the effect that increased activity in the sympathetic vasoconstrictor tone can be reflexly elicited by pain resulting in a diffuse efferent outflow *Adams Ray & Pernow* (1949) demonstrated for instance that an inflamed area is frequently surrounded by a pale zone and that this pallor syndrome can be eliminated by sympathetic block Pain in visceral organs also elicits vasoconstriction in the corresponding dermatome as a result of a reflexly increased flow of impulses from vasoconstrictor fibres (*Wernoe* 1920 *Adams Ray* 1953) The pains in the leg elicited by compression of the nerve root in the present cases might similarly give rise to reflexly increased vasoconstrictor tone and hence a reduced skin circulation particularly in the distal parts of the leg where the autonomic innervation is extensive Such a hypothesis would also explain why the effect on the skin temperature apparently did not coincide with the

10 Lund F (1949) Plethysmographic investigations of the blood circulation in fingers and toes by means of condensor manometer particularly morphological studies of the digital volume pulse *Acta med scand* 13 399
11 Roddie, I C, Shepherd, J T & Whelan R F (1956) Evidence from venous oxygen saturation measurements that the increase in forearm s blood flow during body heating is confined to the skin *J Physiol* 134, 444
12 Wernoe, T B (1920) Aesthesioscopia abdominalis. *Ugeskr Læg* 82 141
13 White, J C & Smithwick, R. H (1948) The autonomic nervous system (2nd edition) Macmillan New York, p 31

Acta orthop Scandinav 40 624-633 1969

Department of Orthopaedic Surgery (Head Professor T Hiertonn M D) and the Department of Diagnostic Radiology (Former Head Professor F Knutsson M D) University Hospital Uppsala Sweden

SKELETAL CHANGES OF THE AMPUTATION STUMP AND THE FEMUR ON THE AMPUTATED SIDE

A *Clinical Investigation*

J A Sevastikoglou U Eriksson & S E Larsson

Received 27 iii 68

Amputation of an extremity is followed by changes affecting the soft tissues the circulation and evidently also the skeleton of the stump Several investigations have been performed earlier concerning the circulatory condition of the limb after amputation (Leriche 1950 Abeatici & Lerrero 1962) The fact that hypervascularity of the stump occurs after amputation is now well established by these investigations Furthermore a relation could be demonstrated (A) between symptoms from the stump such as local tenderness or pain phantom pain and ulceration and a higher mean resting blood flow and (B) between the degree of pain in the amputated leg and the degree of richness and the number of tortuous spiralled arteries in the stump (Eriksson 1965)

Micro radiographic studies showed that the healing of the amputation stump in rabbits proceeds in the same way as the healing of experimental fractures with two fragments (Hulth & Olerud 1962) Studies of the healing of the amputation stump in rabbits with consideration to the vascularity of the bone have provided evidence for a relation existing between increased vascularity of the stump and formation of spurs (Erikson & Olerud 1966) Beyond the referred investigations research concerning the skeletal changes occurring after

This investigation has been aided by grants from the Swedish State Medical Research Council (Contracts Nos Y 171 and B 66-214)



Figure 1 The roentgenologic appearance of the stump in two below knee amputated patients An extreme osteoporosis is present in the left stump one year after amputation the right stump is sclerotic 9 years after the operation

amputation are very scarce and the metabolic condition of the skeletal part of the stump has not yet been investigated It is known from clinical inquiries that after amputation the bone stump shows on X ray a more or less extensive atrophy which sometimes affects the neighbouring parts of the skeleton too In exceptional cases the skeleton of the stump develops however distinct signs of sclerosis (Figure 1)

In order to study the X ray appearance and the changes in metabolic activity of the skeletal parts of the extremity after amputation investigations have been undertaken concerning (A) studies of the roentgenological appearance of the skeleton in amputees and (B) kinetic studies of the skeletal parts of the extremities after experimental below knee amputation in the rat

The present report concerns observations on the appearance of the stump and femur on the amputated side on X ray films as compared with the non-operated leg in a number of patients with unilateral below or above knee amputation An attempt has also been made to correlate existent pain syndrome of the amputated extremity to its state of calcification

MATERIAL AND METHODS

Forty seven unilaterally amputated patients are included in the present material Twenty eight were above knee (Table 1) and 19 below knee (Table 2) amputees. Ten were female and the remaining were male patients The cause of amputation was traumatic in 33 cases In 14 cases amputation was necessitated because of pathological changes of the extremity as peripheral vascular changes or tumour The average age of the patients at the time of amputation was $47\,^{5}/_{12}$ years the youngest patient being 7 and the oldest 80 years old The time elapsed between the amputation and the X ray examination varied from 1 month to 54 years average $8\,^{2}/_{1}$ years Twenty three of the patients were included in an earlier investigation (Eriksson 1965)

Table 1 Above knee amputees

Case no	Sex	Age at amp (yrs)	Cause of amp	Time between amp and examin (yrs)	Degree of decalcification of the stump	Thickness of the cortical bone: Intact femur (mm)	Stump (mm)	Diff (mm)	Degree of pain
1	F	53	Pathol	$1\,^{2}/_{1}$	+	17 0	16 0	1 0	1
2	F	73	Pathol	$1\,^{2}/_{1}$	++	12 0	8 0	4 0	1
3	M	53	Pathol	$1\,^{4}/_{1}$	+++	19 0	8 0	11 0	1
4	M	69	Pathol	1	++	16 0	9 0	7 0	1
5	F	80	Pathol	$^{10}/_{1}$	0	20 0	16 0	4 0	1
6	F	44	Pathol	$^{1}/_{1}$	0	21 0	19 0	2 0	1
7	M	80	Pathol	$1\,^{3}/_{12}$	+	17 0	15 0	2 0	1
8	F	73	Pathol	$^{7}/_{1}$	++	17 5	14 0	3 5	1
9	M	40	Trauma	10	++	15 0	8 0	7 0	3
10	M	41	Trauma	1	+	13 0	12 0	1 0	3
11	M	51	Trauma	8	+	15 0	10 0	5 0	2
12	F	60	Trauma	6	++	17 0	5 0	12 0	3
13	M	22	Trauma	$3\,^{6}/_{1}$	0	16 3	14 0	2 3	1
14	F	43	Trauma	7	+	11 5	8 5	3 0	2
15	M	35	Trauma	5	+	15 5	9 5	6 0	3
16	M	34	Trauma	7	++	17 5	13 0	4 5	1
17	M	38	Trauma	9	+	16 5	13 5	3 0	3
18	M	54	Trauma	1	++	16 0	14 0	2 0	3
19	M	51	Trauma	4	+	22 0	17 0	5 0	1
20	M	7	Trauma	46	+	22 0	9 0	13 0	3
21	M	30	Trauma	$^{10}/_{1}$	++	16 0	14 0	2 0	3
22	M	20	Trauma	7	+	18 0	9 0	9 0	3
23	M	31	Trauma	$/_{1}$	0	18 0	19 0	− 1 0	2
24	M	45	Trauma	8	+	20 0	9 0	11 0	2
25	M	36	Trauma	12	0	21 0	15 0	6 0	2
26	M	55	Trauma	4	+	20 0	16 0	4 0	1
27	M	19	Trauma	49	++	19 0	10 0	9 0	3
28	M	34	Trauma	3	+	16 0	12 0	4 0	2

Table 9 Below knee amputees

Case no	Sex	Age at amp (yrs)	Cause of amp	Time between amp and examin (yrs)	Degree of decalcification of the stump	Thickness of the cortical bone: Intact tibia (mm)	Stump (mm)	Diff (mm)	Femur on the intact side (mm)	Femur on the amp side (mm)	Diff (mm)	Degree of pain
1	M	51	Pathol	3	++	10 0	3 0	7 0	7 0	7 0	0	3
2	M	25	Pathol	11	++	3 0	0	3 0	9 0	4 0	5 0	1
3	F	65	Pathol	2	++	7 0	1 0	6 0	8 0	2 0	6 0	1
4	I	38	Pathol	26	++	7 0	3 0	4 0	5 0	3 0	2 0	3
5	M	56	Pathol	1/12	+	8 0	7 0	1 0	8 0	8 0	0	1
6	I	57	Pathol	1	+++	6 0	0 0	6 0	—	—	—	1
7	M	12	Trauma	9	+	7 0	5 0	2 0	13 0	13 0	0	1
8	M	44	Trauma	3	sclerosis	13 0	8 0	5 0	9 0	9 0	0	1
9	M	60	Trauma	9	++	11 0	1 0	7 0	—	—	—	2
10	M	26	Trauma	3	+	9 0	6 0	3 0	24 0	20 0	4 0	1
11	M	19	Trauma	4	+	5 0	3 0	2 0	6 0	4 0	2 0	1
12	M	27	Trauma	12	++	9 0	5 0	4 0	11 0	11 0	3 0	3
13	M	45	Trauma	6	+	1 0	2 0	—1 0	7 0	7 0	0	3
14	M	15	Trauma	8/1	+	14 0	4 0	10 0	21 0	18 0	3 0	2
15	M	39	Trauma	3	+	11 0	13 0	1 0	7 0	6 0	1 0	2
16	M	24	Trauma	3	+	8 0	4 0	4 0	9 0	8 0	1 0	1
17	M	17	Trauma	1 8/12	++	14 0	11 0	3 0	—	—	—	1
18	M	45	Trauma	3	++	8 0	7 0	1 0	16 0	16 0	0 0	3
19	M	45	Trauma	9	sclerosis	1 0	6 0	—2 0	15 0	15 0	0 0	3

All patients with traumatic amputation complained at the time of examination of some degree of either local pain from the stump or phantom pain which in this investigation has been called pain syndrome The degree of pain syndrome was evaluated on a 3 graded scale according to Eriksson (1965) i e 1 no or insignificant pain 2 moderate pain and 3 severe pain in the amputated leg

The condition of the skeletal parts of the amputated and of the contralateral, intact extremity was examined on frontal projection of both legs on X ray films and it was estimated (A) by a subjective judgement of the degree of radioopacity by each of the authors separately the degree of bone atrophy was classified as uncertain (0) moderate (+) pronounced (++) extreme (+++) and as sclerosis. (B) According to Barnett & Nordin (1960) the thickness of the cortical bone was accepted as a measure of the degree of the bone atrophy The difference between the outer and inner diameter of the diaphyses of the bones of the intact and the amputated leg was measured always equidistantly from skeletal landmarks as the top of the intracondylar eminence of the tibia the intracondylar groove of the femur or the top of the major trochanter Portions of the stump showing involvement on the healing process were avoided in these measurements The results were expressed as difference in mm between the stump and the contralateral intact bone or the femur on the amputated and on the non amputated side respectively

RESULTS

The distribution of the material and the obtained results are demonstrated in Tables 1 and 2

The appearance of the stump on the X ray films was found extremely atrophied in only two cases A pronounced bone atrophy of the stump was present in 17 cases In 21 cases the stump was moderately atrophic in another 5 cases there were no certain signs of bone atrophy In two cases pronounced sclerosis of the stump was present

The cortical bone of the stump in above knee amputees was in all cases except one (No 23 Table 1) thinner than that of the contralateral femur The difference varied between —1 and 13 mm the mean value being 5 1 mm

In below knee amputees the cortical bone of the stump was thinner in 17 and thicker in another 2 patients The mean difference was 3 5 mm and differences in thickness varied between —2 and 10 mm

In below knee amputees the femur could be examined in 16 cases In cases Nos 6 and 9 no X rays of the femur were available In case No 17 there was a recently healed diaphyseal fracture and any reliable measurement of the thickness of the cortical bone was therefore impossible In the 16 below knee amputees where measurements of the thickness of the cortical bone of the femurs were performed there was no difference between the amputated and the non amputated side

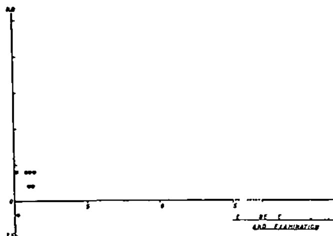


Figure 2 Difference in mm between the cortical thickness of the amputated and the non amputated femur at different times after intervention

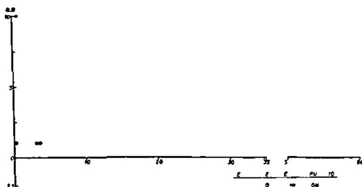


Figure 3 Difference in mm between the cortical thickness of the amputated and the non amputated tibia at different times after the intervention

in 7 cases In the remaining 9 cases the cortical bone of the femur on the amputated side was somewhat thinner the differences ranging between 1 and 6 mm The mean value was 3 0 mm

In Figures 2–4 the cortical differences of the individual patients related to the time elapsed between the operation and the examination are demonstrated It seems from these figures that the amputation stump developed a more pronounced thinning of the cortical bone than the femur in below knee amputees

Ten above knee and six below knee amputees suffered from severe

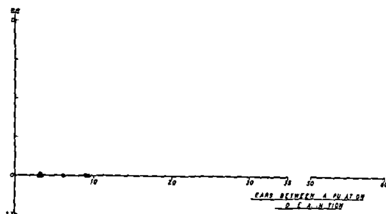


Figure 4 Difference in mm between the cortical thickness of the femur on the amputated and the non amputated side in below knee amputees at different times after the intervention

pain Two of the 14 patients amputated because of pathological changes both below knee amputees had severe pain Among the 33 traumatic amputees 23 complained of severe pain The frequency of severe pain was thus much higher in patients amputated because of traumatic than pathological causes (Table 3) No distinct correlation existed between cortical atrophy and the degree of pain (Table 4) The observation was made, however that in patients with extreme bone atrophy of the stump there was practically no pain syndrome present (Table 5)

DISCUSSION

The reported results demonstrate that the stump in below or above knee amputees compared with the non amputated contralateral leg, develops some degree of bone atrophy expressed as decreased radio

Table 3 Relation between the degree of pain syndrome and the cause of amputation in above knee (AK) and below knee amputees (BK)

Type of amputation	Cause of amputation	Degree of pain syndrome 1	2	3
AK	Trauma	4	6	10
	Pathol	8	0	0
BK	Trauma	6	3	4
	Pathol	4	0	2

Table 4 Relation between the degree of pain syndrome and the difference in the cortical thickness of above knee (AK) and below knee amputees (BK)

		Degree of pain syndrome 1	2	3
Difference in the cortical thickness in mm	AK			
	mean	3 5	4 7	6 2
	number	12	6	10
	range	—4-11	—1-11	1-12
	BK			
	mean	3 5	6 0	2 7
	number	10	3	6
	range	1-6	1-10	—2-7

Table 5 Relation between the degree of pain syndrome and decalcification of the stump in above knee (AK) and below knee (BK) amputees

	Degree of decalcification	Degree of pain syndrome 1	2	3
AK	+	4	4	5
	++	4	0	5
	+++	1	0	0
BK	+	5	2	1
	++	3	1	4
	+++	1	0	0

opacity of the bone on X ray films as well as a decrease of the thickness of the cortical bone of the stump

The observation made that some degree of atrophy of the bone stump was present in 44 out of 47 cases indicates that this pheno menon is extremely common after amputation These stump changes seem to be irreversible as indicated in Figures 2 and 3 Sclerosis of the stump was present in only two cases of below knee amputation (Nos 8 and 19 Table 2) where the thickness of the cortical bone of both the stump and the femur on the amputated side was somewhat greater than that of the bones of the non amputated side

The observations regarding the femur on the non amputated side in cases of below knee amputations show that bone atrophy was pre- sent in 9 out of 16 cases This suggests either that this change is less

common than the respective change of the stump or that it has a regressive character In the latest case the bone atrophy affecting the femur should be dependent upon time decreasing gradually and disappearing later Experimental data, to be reported elsewhere may support this evidence (Sevastikoglou & Larsson unpublished) Nilsson (1966) in a clinical study concerning post traumatic osteopenia found bone atrophy of the ipsilateral femur long after fracture of the tibia and thus concluded that these changes are irreversible

Symptoms of pain from the stump were present in some degree in practically every case No relation could be found between the presence of "pain syndrome and the roentgenological appearance of the skeletal parts in this material except for the fact that in patients with extreme bone atrophy of the stump there was no pain syndrome' However since this observation concerned only two patients its validity is questionable

SUMMARY

The degree of radioopacity of the amputation stump and in cases of below knee amputation of the femur on the amputated side has been examined in 28 above knee and 19 below knee amputees

Determinations were based on estimations of the appearance of the skeletal parts as well as on measurements of the thickness of the cortical bone made on X ray films Comparison was made to the corresponding parts of the non amputated leg

The amputation stump itself both after below- or above knee amputation undergoes bone atrophy which seems to be of a permanent character In below knee amputees the femur on the amputated side showed signs of bone atrophy in some cases but not consistantly The bone atrophy of this skeletal part might be of a transient character

There was no certain evidence of a correlation existing between pain syndrome after amputation and the radiological appearance of the bone stump

REFERENCES

Abeatici S & Ferrero R (1953) Studio arteriografico dei monconi d amputazione Ricerche sperimentali *Minerva chir* 8 452

Barnett E & Nordin B E (1960) The radiological diagnosis of osteoporosis A new approach *Clin Radiol* 11 166

Erikson U (1962) Circulation in traumatic amputation stumps An angiological and physiological investigation *Acta radiol (Stockh)* Suppl 238

Erikson U & Hulth A (1962) Circulation of amputation stumps Arteriographic and skintemperature studies *Acta orthop scand* 32 159

Erikson U & Olerud S (1966) Healing of amputation stumps—with special reference to vascularity and bone *Acta orthop scand* 37 20

Hulth A & Hogstrom S (1961) Bestamning av pO_2 och pH i ven och artarblod på amputerade *Nord Med* 66 1136

Hulth A & Olerud S (1962) Studies on amputation stumps in rabbits *J Bone Jt Surg* 44-B 431

Leriche R (1950) Etude critique des mecanismes de la douleur chez les amputés. *J Chir (Paris)* 66 5

Nilsson B E R (1966) Posttraumatic osteopenia *Acta orthop scand.* Suppl. 91

Sapia, E. S de & Assenso G (1954) Le Turbo dell irrorazione sanguigna nei monconi di amputazione Ricerche sperimentali. *Arch Ortop (Milano)* 67 361

Sevastikoglou J A & Larsson S E (Unpublished) Changes in composition and metabolic activity of the skeleton of the extremity of the adult rat I After below knee amputation

Acta orthop Scandinav 40 634–641 1969

Department of Orthopaedic Surgery (Head C Hirsch M D)
University of Goteborg Sweden

SYNOVIAL pH IN RHEUMATOID KNEE JOINTS

I The Effect of Synovectomy

Ian Goldie & Alf Nachemson

Received 2 i 68

Inflammatory reactions are among other characteristics distinguished by a local acidosis This varies in relation to the intensity of the inflammatory state For example in the initial stages when there is a predominance of polymorphonuclear leucocytes the hydrogen ion concentration is relatively low and the pH ranges around 7 4 With further development of inflammation and correlated to this a change in the cellular morphology towards the mononuclear phagocytic type the alkalinity subsides and there is a drop in pH to levels around 6 5 (Menkin & Warner 1937) This progressive acidity which parallels inflammation in duration of time depends on a number of factors, e g the influence of protein split products such as amino acids (Ropes & Bauer 1953) or as Menkin & Warner (1937) and Menkin (1956) suggest, on the result of increased glycolysis with conversion of sugar into lactic acid ultimately resulting in an uncompensated acidosis as there is no corresponding increase in the alkali reserve

It can then be expected that a chronic inflammatory condition like rheumatoid arthritis might exhibit a certain degree of acidosis in the articular exsudates Ropes & Bauer (1953) determined the pH in normal human synovial fluid obtained at autopsy and found it to be 7 39 In 8 cases with rheumatoid arthritis the pH averaged 7 22 The determinations were made extracorporeally after aspiration In a comparative study of pH in normal and rheumatoid synovial fluids Cummings & Nordby (1966) found a pH of 7 43 in 7 normals with a range of 7 31–7 64 In 8 rheumatoid patients the pH of the synovial fluid was 7 22 with a variation from 7 08 to 7 28 In neither of the above men

Supported by grants from Konung Gustaf V s 80 årsfond

tioned works has the duration of the rheumatoid disease before the pH determination been stated

It is apparent that in synovial fluids of rheumatoid arthritis there is an increased hydrogen ion concentration though of little degree According to Dingle & Page Thomas (1956) this is part of the glycolytic metabolism in the diseased synovial tissue The proposed destructive action of this metabolism may be counteracted by the administration of anti inflammatory drugs (Dingle & Page Thomas 1956) In consequence it appears plausible that the surgical removal of inflamed synovial tissue a common method of treatment in rheumatoid arthritis should alter the hydrogen ion concentration of the synovial fluid

In this study we have investigated the pH of articular fluid by an intra articular measuring method in normal knee joints and rheumatoid knee joints before and after synovectomy

MATERIAL

Three groups were selected one representing normal knees (10) another rheumatoid knees (12) and the third rheumatoid knees subjected to synovectomy (10) prior to this investigation

Table 1 Hydrogen ion concentration of synovial fluid in normal knees

Age	Sex	Diagnosis	pH
51	♂	Multiple sclerosis	7.2
53	♀	Femoral neck fracture	7.2
46	♂	Distorsion talocrural lig	7.1
44	♂	Ganglion	7.1
23	♂	Talipes	7.3
26	♂	Arthritis wrist	7.4
57	♂	Arthritis hip	7.2
53	♂	Arthritis hip	7.7
24	♂	Granuloma lower limb	7.4
48	♂	Talipes	7.4
			Mean 7.3

Normals Patients who were admitted to hospital for ailments not involving the knee joints were measured. Permission was granted by the patients. The diagnoses of the patients measured are seen in Table 1 The ages varied from 23 years to 73 years

Rheumatoid arthritis Only patients selected for synovectomy were measured. All had a swelling of the knee with a bulging, oedematous synovial tissue and increased

articular exudate The duration of disease from onset until time of measurement varied from 2–6 years. The ages of the patients were from 48 to 74 years. All patients fulfilled the criteria of the American Rheumatology Association Some of the patients were subjected to cortisone treatment, which will be commented upon in the discussion of results. These pH readings (2) were excluded from the statistical analysis. Thus 10 patients were evaluated.

Rheumatoid arthritis after synovectomy The time between synovectomy and measurement ranged from 5 to 36 months (mean 14 months) Of these 3 were also measured before synovectomy (Table 3) but 1 was still receiving cortisone treatment at the time of measurement and the value was therefore not included in the statistical analysis. One more patient was excluded for the same reason which thus left 8 patients for statistic analysis. The operative procedure was the same as described by Goldie (1968)

Table 2 Hydrogen ion concentration in synovial fluid of rheumatoid knee joints Steroid treated patients excluded in the statistical calculations

Age	Sex	Duration of illness (yrs)	pH	Comment
48	♂	3	6.0	Also measured after synovectomy
74	♂	5	6.4	Also measured after synovectomy
62	♀	7	6.2	
69	♀	10	6.1	
73	♀	20	6.8	Fibrotic synovial tissue
54	♀	4	7.3	Fibrotic synovial tissue
58	♀	4	7.3	Fibrotic synovial tissue
56	♀	8	6.5	
64	♀	6	6.6	
36	♂	5	6.9	
			Mean 6.6	
73	♀	10	7.8	Massive *steroid* treatment
53	♀	5	7.3	Also measured after synovectomy Osmium and *steroid treated*

Table 3 Hydrogen ion concentrations in synovial fluid of synovectomised rheumatoid knee joints Steroid treated patients excluded in the statistical calculations

Sex	Age	Time between operation and measurement (mths)	pH	Comments
48	♂	13	6 3	Measured before synovectomy
74	♂	6	6 8	Measured before synovectomy
58	♀	30	6 6	
58	♀	5	7 1	
59	♀	36	6 6	
64	♀	9	6 7	
36	♂	14	6 9	
57	♀	18	7 3	Fibrotic tissue
			Mean 6 8	
53	♀	6	7 1	Measured before synovectomy *steroid* treated
59	♀	9	7 0	*steroid* treated

METHOD

All patients were measured under general fluothane anaesthesia with a needle type pH electrode especially constructed for measurement in deep somatic tissues like intervertebral discs (Nachemson 1969) The length was 145 mm diameter 1 2 mm The electrode consists of purest antimony and, as a reference a calomel electrode was used which was placed together with the patient s finger in a solution of *physiological saline The advantages and disadvantages of an antimony electrode* have previously been described by Bates (1964) Recordings were made from Radiometer pH Meter 25 25SE 2, The calibration of the pH electrode was made from different standard buffer solutions immediately after taking the reading inside the knee joints, and the values obtained were corrected according to the calibration curves obtained

The electrode was chemically sterilized in diglutaraldehyde 2 5 per cent for at least 2 hours prior to measurement (Borick Dondershine & Chandler 1965)

The knee joint cavity was reached by a larger needle (diameter 2 1 mm) with a pointed mandrin which was then extracted and the electrode inserted. Care was always *taken to place the tip of the electrode in free joint cavity* Reading was taken after 2 min stabilization time. In some cases the electrode was then moved to another part of the knee joint cavity without noticeable change in pH

The authors are indebted to Engineer A Meissl Department of Thoracic Surgery Karolinska Sjukhuset Stockholm Sweden *for the construction of the electrode*

RESULTS

In the group of normals it became evident very soon that it was most essential to perform the measurements in patients who had no injurious involvement of their knees Thus patients with a previous history of knee affliction were excluded as it was shown among other things that such an ailment as e g habitual dislocation of the patella apparently affected synovial tissue and fluid in a way that increased hydrogen concentration ensued This was thought to be due to a low grade chronic synovitis which also was verified at operation In Table 1 a summary of the results of normals is given

The pH measurements coincide with those reported elsewhere (Ropes & Bauer 1953 Howell 1965 Cummings & Nordby 1966)

Rheumatoid knees In this group it was obvious that the pH was decidedly lower than that reported in other series The only exceptions were those who had been subjected to corticosteroid treatment where a slight elevation was noted but still below or near normal The mean value was 6 6 with a lowest registration of 6 0 and a highest of 7 8 The latter had not only received intra articular injections of corticosteroid but also had systemic cortisone treatment at the time of surgery (Table 2)

Table 4

	Normal knees	Rheumatoid knees	Rheumatoid synovectomized knees
Mean	7 30	6 61	6 79
SD	0 053	0 214	0 098
T statistics	←t_{diff} = 4 42→	←t_{diff} = 0 95→	
	←——————t_{diff} = 4 01→		

Rheumatoid knees after synovectomy In this group as well as in the previous small variations were noted especially in those receiving corticosteroid treatment (Table 3) The overall results however disclosed a marked high hydrogen ion concentration with a pH around 6 8 with a lowest registration of 6 3 and a highest of 7 1 Also in this group the highest pH values were obtained in those knee joints into which hydrocortisone had been injected

A statistical evaluation of the differences between these three groups revealed that there was a highly significant difference between the pH values obtained in the normal knees compared with both the non

synovectomized (t_{diff} = 4.42) and the synovectomized (t_{diff} = 4.01) group (Table 4).

There was no difference between the two latter groups.

As mentioned above those patients who received corticoid therapy at the time of measurement were excluded from this statistical calculation.

COMMENTS

Previous investigations on the pH of synovial fluid have been carried out on samples aspirated from the joints (Ropes & Bauer 1953, Dingle & Page Thomas 1956, Howell 1965, Cummings & Nordby 1966). The values obtained have ranged around 7.4. In our investigation the method employed has permitted the registrations to be made intra-articularly *in vivo*. This, however, has not caused any greater difference in the estimation of the pH values in apparently normal knee-joints, all of which have fallen in the range of 7.3.

There is, on the other hand, a conspicuous difference in the readings obtained in the group with rheumatoid arthritis. In this investigation the hydrogen ion concentration has been more pronounced than in other reported series. The values obtained have been in the range of 6.7 as compared to 7.2–7.3 in other communications (Ropes & Bauer 1953, Cummings & Nordby 1966). The reason for this is uncertain but could depend on changes occurring in the aspirated samples where for instance oxygenation may influence the hydrogen ion concentration. This assumption was to some extent verified in three cases where the aspirated fluid showed pH 7.6, 7.6 and 7.4, whereas the pH in the knee joint cavity was 6.6, 6.7 and 6.8 respectively.

The pH recordings in the rheumatoid knees of this investigation coincide with earlier observations of acidity in inflamed tissues by Menkin & Warner (1937). This has been confirmed by others (Hamerman, Stephens & Barland 1961).

The pathomorphology of rheumatoid arthritis discloses in synovial tissues features all of which are indicative of a chronic non-specific inflammation. It thus appears that the pH determinations in this study depict the local intra-articular acidosis which parallels the cytologic picture of the synovial tissue.

If then these tissues are removed as is done in synovectomy, the question arises whether there will be any change in the pH. Our investigation has disclosed that there remains a pronounced acidity long after the time for regeneration, which is 60–90 days (Stevens & White

field 1966 Preston 1967) Some state (Marmor 1967 Preston 1967 McEwen 1967) that the synovial tissue which regenerates after synovectomy is quite normal Own investigations (Goldie 1967) have shown however that the new synovial tissue replacing the old contains features similar to those found in the tissue removed at first synovectomy and have like these been classified by pathologists as "chronic" non specific inflammation With this in mind it might then not be astounding that the hydrogen ion concentration remains high in rheumatoid articulations after synovectomy

The normal or near normal readings which have been registered in the corticosteroid treated cases may be explained by the anti inflammatory action of these drugs

It is at the present time impossible to ascertain the different factors causing the high hydrogen ion concentration In spite of the fact that this concentration remained unaltered after synovectomy the patients claimed clinical improvement Other objective tests (Goldie 1968) have however indicated a normal function of the regenerated synovial tissue These investigations have included intra articular temperature recordings and thermographic registrations which depict the circulatory conditions whereas the test of hydrogen ion concentrations may be based on the activity of the synovial cellular elements

SUMMARY

Using an intravital method the hydrogen ion concentration has been estimated in synovial fluids of normal (10) rheumatoid (12) and synovectomized (10) rheumatoid knee joints

Normal knee joints showed a pH of 7 3 rheumatoid of 6 6 and rheumatoids at varying time after synovectomy a value of 6 8 with a statistically significant difference between the first and the two latter groups The observations are in alignment with current ideas of an increased hydrogen ion concentration being paralleled with tissue changes of the chronic inflammatory type which characterized the synovial tissues in rheumatoid arthritis before and after synovectomy

REFERENCES

Bates R. C (1964) *Determination of pH Theory and practice* J Wiley & Sons, New York p 252

Borick P M Dondershine F H & Chandler V L (1965) Alkalinized glutaraldehyde a new antimicrobial agent *J pharm Science* 53 1273–1275

Cummings N A & Nordby G L (1966) Measurements of synovial fluid pH in normal and arthritic knees *Arthr Rheum* 9 47–56

Dingle J T M & Page Thomas D P (1956) *In vitro* studies on human synovial membrane A metabolic comparison of normal and rheumatoid tissue *Brit J exp Path* 37 318–323

Goldie I (1967) *Objective evaluation of results of synovectomy in rheumatoid arthritis* British Orthopaedic Association London

Goldie I (1968) Yet unpublished data

Hamerman D Stephen M & Barland P (1961) *Inflammation and disease of connective tissue* W B Saunders Philadelphia pp 158–168

Howell D (1965) Preliminary observations on local pH in gouty tophi and synovial fluid *Arthr Rheum* 8 736–737

Marmor L (1967) *Surgery of rheumatoid arthritis* H Kimpton London

Menkin V (1956) Biology of inflammation *Science* 123 527–534

Menkin V & Warner C R (1937) Studies on inflammation XIII Carbohydrate metabolism local acidosis and the cytological picture in inflammation *Amer J Path* 13 25

McEwen C (1967) *Early synovectomy in rheumatoid arthritis* Int Study Centre Rheum Dis Amsterdam

Nachemson A (1969) Intradiscal measurements of pH in patients with lumbar rhizopathies *Acta orthop scand* 40 23–42

Preston R L (1967) *Early synovectomy in rheumatoid arthritis* Int Study Centre Rheum Dis Amsterdam.

Ropes M W & Bauer W (1953) *Synovial fluid changes in joint disease* Harvard University Press Cambridge

Stevens T & Whitefield G A (1966) Synovectomy of the knee in rheumatoid arthritis *Ann rheum Dis* 25 210–227

Acta orthop. Scandinav. 40, 642–652, 1969

Rheumatism Foundation Hospital (Head: Prof. Veikko Laine; Chief of the Surgical Department: Kauko Vainio, M.D.), Heinola, Finland

ARTHRODESIS OF THE TC OR PANTALAR JOINTS IN RHEUMATOID ARTHRITIS

VEIJO VAHVANEN

Received 29.x.68

All previous follow-up studies have been performed on series in which talocrural (TC) or pantalar arthrodesis was carried out for reasons other than rheumatoid arthritis (RA). So far no follow-up study has been published on a series in which RA constituted the indication for these operations. The most extensive follow-up investigations are those published by Guildal & Sodeman (1930), Hamsa (1936), Laboll (1939), Dahmen & Meyer (1965) and Waugh et al. (1965). Not even the series of Waugh et al., which consisted of 116 patients on whom pantalar arthrodesis had been carried out, comprised any case of RA.

OWN INVESTIGATIONS

Material and Indications for Operation

The series consists of 32 arthrodeses of the TC or pantalar joints performed on 31 patients with definite RA (Ropes et al. 1959). There were 23 female patients and 8 male patients. All operations were performed at the Rheumatism Foundation Hospital, Heinola, during the years 1953–1965. The series comprises only patients whose RA began after the age of 15. Pantalar arthrodesis, including the talocrural, talocalcaneal, talonavicular and calcaneocuboid joints, was performed only on *five* rheumatic ankles. The total number of TC arthrodeses was 27, performed on 26 patients. In one case TC arthrodesis was successively performed on the ankles of a female patient at an interval of 12 years. The patient has continued her work as a hair dresser. In addition to TC arthrodesis the talonavicular joint was fused in three cases and also the talocalcaneal joint in three cases. In four feet triple arthrodesis had been performed prior to arthrodesis of the TC joint

The duration of RA in the ankle ranged from 1 to 34 years the average being 14 years The operative age of the patients ranged from 30–64 years the average being 46 years In 29 cases the ankle joints became inflamed at the beginning of the disease (within one year) In these patients RA has been symmetrical and severe

The follow up time from the operation ranged from one to 14 years the mean being 4½ years Twenty two patients were clinically and roentgenologically examined by the author and 9 patients were fol lowed up by means of questionnaires Eight patients replied personally and one questionnaire was filled in by relatives Two patients died (8 and 6 years postoperatively) but in one of these cases follow up ex amination had already been performed Both patients probably died of cardiac infarction

The indications for TC arthrodesis were persistent pain in the ankle joint and destructive roentgenological changes of at least stage II (Steinbrocker et al 1949) As a rule persistent inflammation had been present for many years Because of the pain the patient could not walk without a cane or crutches In one case painful equinus position of the ankle joint constituted the indication It was regarded as a condition however that the subtalar joints were clinically symptom free They had either been anchylosed in a satisfactory position several years ago or the slight motion left was completely painless If painful motion remained or a disturbing deformation was present pantalar arthrodesis was performed at the same time (five cases only)

Preoperative Clinical and Roentgenological Findings

All ankles on which operation was planned were markedly swollen and painful on motion and weight bearing All these patients needed a cane or crutches on walking The total active motion was slightly less than 20 degrees in the 27 ankles in question The average dorsal flexion of the remaining five ankles was 8 degrees the average plantar flexion 23 degrees In five cases only was the motion of the subtalar joints almost normal in one case it was limited up to one third and in the remainder these joints were rigid Active motion was examined with the knee joint in maximal extension

Deformities (1) Planovalgus severe (valgus over 20 degrees) in three feet moderate (over 10 degrees) in ten feet and slight (10 de grees or less) in eight feet For measurement of calcaneal valgus a special device was used (Vahvanen 1967) (2) Varus of the forefoot



Figure 1 *Destroyed TC joints in a case of over ten years duration Narrowing and erosions in both joints In addition osteoarthrosis is present*

eight feet In two of these there was slight calcaneal varus, in one also moderate cavus (3) Cavus calcaneus one foot (4) Equinus of about 30 degrees one ankle

The roentgenological stage of the TC joint (Steinbrocker et al 1949) was stage II in 5 ankles stage III in 27 ankles In six TC joints severe destruction was present and the joint space was very narrow The roentgenological stage of the subtalar joints (the changes in one or another of the three subtalar joints) was stage I in one foot, stage II in seven feet stage III in 16 feet Triple arthrodesis had previously been performed on four feet Of the remaining four feet no X ray pictures were available

Operative Methods

In this series arthrodesis of the TC or pantalar joints was performed by five different methods

1 Blocking of the TC joint by a short cortical spongy bone graft as suggested by Cramer (1910) and Lasker (1923) 13 ankles The TC joint was opened by a straight anterior incision and a bone graft from the iliac crest was applied between the tibia and talus in which an appropriate groove had been modelled in the direction of the leg In three cases the talonavicular joint too was fixed by a bone graft No metal fixation was used

2 Adams (1948) operation 6 ankles In one case only was the talocalcaneal joint too opened and debrided because of severe painful



A



B

Figures 2 A and B The same feet as in Figure 1 after arthrodesis of the right TC joint (Adams) The operation was successful the joint shows union and is completely stable and painless The subtalar joints of the right foot are in better condition than those of the left foot which cause discomfort both the TC and subtalar joints being painful

destruction The distal part of the fibula was fixed by screws as an on lay graft to the tibia and talus

3 Compression arthrodesis by Charnley s method (1951) 5 ankles All these operations were performed in slightly different ways but in every case the TC joint was debrided The talocalcaneal joint was also debrided if it was not already anchylosed Compression was effected by strong Steinman nails through the tibia and calcaneus In three cases the distal part of the osteomized fibula was used as a graft on the lateral or anterior aspect of the TC joint

4 Pantalar arthrodesis by the method of Guildal & Sodeman (1930) 5 ankles The distal part of the osteomized fibula was fixed as an on lay graft by one screw to the tibia and the talus In addition triple arthrodesis was performed by the technique previously described by the author (1967) In one case the talocalcaneal joint was not opened *because it was anchylosed in a good position and was painless*

5 A sliding graft from the tibia to the talus 3 ankles This method has been used only in the last few years By anterior longitudinal incision the TC joint was debrided and a bone graft (the shape of a spear head) was chiselled from the anterior tibial crest The sharp distal part was applied deep to the talus and the broader and thicker proximal part was fixed by one screw to the anterior part of the tibia

In all these different methods small spongy chips were applied to the debrided joints and around the graft A below knee well moulded plaster cast was applied which was changed after two weeks (in Charnley s method after four weeks) and a heel was applied under the cast Partial weight bearing was then allowed The total immobilization time was eight weeks except in two cases in which it was longer The TC joint was usually positioned in five degrees plantar flexion in the males and ten degrees plantar flexion in the females The foot was positioned into slight (5 degrees) calcaneal valgus

Anaesthesia

General anaesthesia (ether) was used in 26 cases and spinal anaesthesia in 2 cases In 4 cases the operation was carried out under combined sciatic femoral nerve block (Moore 1954 Vahvanen 1964) No complications from anaesthesia occurred In all cases the operation was performed in a bloodless field

RESULTS OF THE 32 TC OR PANTALAR ARTHRODESES

The results were classified as good fair or poor on the following criteria

Good result The fused joints were stable and the ankle was painless In addition the foot showed no disturbing deformity

Fair result Slight deformity was present but this did not cause much discomfort Slight swelling and pain on walking sometimes occurred

Table 1 Results of 32 TC or pantalar arthrodeses

	No feet	No patients	♂/♀	Good	Fair	Poor
Pantalar arthrodesis (Guildal)	5	5	5 ♀	4	1	0
Talocrural arthrodesis	27	26	19 ♀ 7 ♂	16	6	5
Total	32	31	24 ♀ 7 ♂	20 (62%)	7 (22%)	5 (16%)

Table 2 The results of 27 TC arthrodeses performed by different methods

Method	No feet	Good	Fair	Poor
Blocking of the TC joint with transplanted cortical spongy bone graft from the iliac crest	13	8	2	3
On lay graft from the fibula (Adams)	6	4	2	0
Arthrodesis by compression according to Charnley	5	3	2	0
Sliding graft from the tibia	3	1	0	2
Total	27	16 (59%)	6 (22%)	5 (19%)

Poor result Pseudarthrosis was present or the foot was still painful

The results were good in 20 ankles (62 per cent) fair in 7 ankles (22 per cent) and poor in 5 ankles (16 per cent) According to the subjective opinions of the patients the results were good in 20 ankles

fair in 9 ankles and poor in 3 ankles Two pseudarthrosis of the TC joint were almost painless slight pain being caused only by major stress

In the good cases (20 ankles) postoperative swelling and pain persisted for 1–24 months, the average being 9 months In the fair ankles major postoperative discomfort occurred for 1–36 months the average being 11½ months Two patients had used a brace for keeping the ankle in good position until pain in the pseudarthrotic joint had disappeared nearly completely In general the patients could walk well Only five patients occasionally used a cane or crutches because of a painful knee or hip joint

Postoperative Equinus Position of the TC Joint

Slight motion being present in five ankles this analysis refers to 27 ankles In the females (21 ankles) the mean angle of the equinus was 11 degrees in the males (6 ankles) about 4 degrees These mean values nearly coincide with what was set up as a goal of the operation All patients were satisfied with the position of the ankle The females used heels of 2½–5 cm in the shoe In two cases the ankle was positioned at 90 degrees, because extension of the knee joint was slightly limited

Findings in the Subtalar Joints at Follow up

A moderate degree of painless motion was present in two feet only the remainder being anchylosed Preoperatively moderate motion was present in six feet On postoperative X ray examination of 14 feet the distribution of changes of various stages (Steinbrocker et al) in one or other of the subtalar joints was as follows stage I four feet stage II six feet stage III four feet The subtalar joints of nine feet were fused and X ray pictures of the remaining nine feet were not available

Detailed Analysis of the Results

Good results (20 ankles) In one foot slight calcaneovarus was present and in another two feet a slight cavus deformity which in one case was combined with slight calcaneovarus These deformities caused no discomfort

Fair results (7 ankles) In these cases the operated joints were well fused but for some reason or another slight pain on walking persisted Planovalgus of over 15 degrees was a cause of discomfort in

three cases Varus of the forefoot caused discomfort in a further three cases In two of these slight painful motion of the Chopart joint was still present In these cases the Chopart joint had not been operatively fused In the third case severe postoperative swelling and pain were present for 1½ years During this time the Chopart joint had probably fused in a position of slight varus of the forefoot In one foot only slight planovalgus was present but nonetheless moderate pain occurred on walking This was probably due to the fact that all subtalar joints had not fused spontaneously and slight passive painful motion was still present in the unfused joints

Table 3 Causes of the poor or fair results in 32 TC or pantalar arthrodeses

Result	Total no feet	Planovalgus	Varus of the forefoot	Painful subtalar joints	TC pseudarthrosis
Fair	7	3	3	1	0
Poor	5	0	0	0	5
Total	12	3	3	1	5

Poor results (5 ankles) Pseudarthrosis of the TC joint was present in five cases Two of these ankles had been treated by the sliding graft method three by blocking of the TC joint with a transplanted graft from the iliac crest Of the first mentioned ankles one was re-operated on by Adams s technique because of pain about one year from the first operation In the other case re operation was planned The last mentioned three pseudarthroses were followed up for at least eight years One patient did not experience any discomfort on walking Another patient was living in a home for the aged and occasionally used crutches for reasons other than the pseudarthrosis The subtalar joints were fused and the foot was in a slight varus position The ankle of the third patient was very painful and the forefoot was in a disturbing varus position At the primary operation an attempt was made to correct this deformity by anchylosing the talonavicular joint also This did not succeed slight active and passive motion of both the TC and the talonavicular joints still being observed as soon as one year after operation Varus of the forefoot had increased at the time of the follow up examination This patient died of cardiac infarction about eight years after the operation

fair in 9 ankles and poor in 3 ankles Two pseudarthrosis of the TC joint were almost painless slight pain being caused only by major stress

In the good cases (20 ankles), postoperative swelling and pain persisted for 1–24 months the average being 9 months In the fair ankles major postoperative discomfort occurred for 1–36 months the average being 11½ months Two patients had used a brace for keeping the ankle in good position until pain in the pseudarthrotic joint had disappeared nearly completely In general the patients could walk well Only five patients occasionally used a cane or crutches because of a painful knee or hip joint

Postoperative Equinus Position of the TC Joint

Slight motion being present in five ankles this analysis refers to 27 ankles In the females (21 ankles) the mean angle of the equinus was 11 degrees in the males (6 ankles) about 4 degrees These mean values nearly coincide with what was set up as a goal of the operation All patients were satisfied with the position of the ankle The females used heels of 2½–5 cm in the shoe In two cases the ankle was positioned at 90 degrees because extension of the knee joint was slightly limited

Findings in the Subtalar Joints at Follow up

A moderate degree of painless motion was present in two feet only the remainder being anchylosed Preoperatively moderate motion was present in six feet On postoperative X ray examination of 14 feet the distribution of changes of various stages (Steinbrocker et al) in one or other of the subtalar joints was as follows stage I four feet stage II six feet stage III four feet The subtalar joints of nine feet were fused and X ray pictures of the remaining nine feet were not available

Detailed Analysis of the Results

Good results (20 ankles) In one foot slight calcaneovarus was present and in another two feet a slight cavus deformity which in one case was combined with slight calcaneovarus These deformities caused no discomfort

Fair results (7 ankles) In these cases the operated joints were well fused but for some reason or another slight pain on walking persisted Planovalgus of over 15 degrees was a cause of discomfort in

spongy bone seems to occur satisfactorily in rheumatoid patients since only three pseudarthroses occurred when arthrodesis of the TC joint was performed by means of a short transplanted bone graft from the iliac crest and the total immobilization time was only eight weeks In many cases bony union probably did not occur until after eight weeks since discomfort persisted for a long time In the author's opinion it is advisable to avoid weight bearing for about 4–6 weeks and to keep the foot immobilized for about 10–12 weeks Especially because of the need to move the knee joint the plaster cast must leave this joint free For the same reason the bone graft should be firmly fixed to the tibia and the talus After pantalar arthrodesis in particular a longer non weight bearing time should be used in order to prevent the calcaneus from slipping back into valgus Because of the good union in RA the immobilization time may be somewhat shorter than after corresponding operations on other indications

SUMMARY

The present series consists of the 32 arthrodeses carried out on rheumatoid ankles i e five pantalar and 27 TC arthrodeses Follow up examinations were performed an average of 4½ years after operation The results were good in 20 ankles (62 per cent) fair in 7 ankles (22 per cent) and poor in 5 ankles (16 per cent) According to the subjective opinions of the patients the results were poor in only three ankles

The five pantalar arthrodeses were successful but one foot remained in complete planovalgus position which caused some discomfort Hence the result was classified as fair The results of TC arthrodesis were good in 16 cases (59 per cent) fair in 6 cases (22 per cent) and poor in 5 cases (19 per cent) The latter showed pseudarthrosis of the TC joint Guildal's Adams's and Charnley's methods gave the best results Union of spongy bone was found to occur satisfactorily in rheumatoid patients Attention should be paid to firm fixation and sufficient duration of immobilization

If the subtalar joints are painful and/or marked deformity is present it is advisable to perform pantalar arthrodesis Special attention should be paid to correction of the deformity

Destruction of the TC joint is relatively infrequent and mainly results from a rheumatoid process persisting for many years Arthrodesis should be performed if a destroyed TC joint is persistently pain-

ful because painless anchylosis of the joint cannot be expected to occur for many years if the treatment is conservative

REFERENCES

Adams J C (1948) Arthrodesis of the ankle Experiences with the transfibular approach *J Bone Jt Surg* 30 B 506

Charnley J (1951) Compression arthrodesis of the ankle and shoulder *J Bone Jt Surg* 33 B 180

Cramer K (1910) Beitrage zur Arthrodese des Talocruralgelenkes *Zbl chir mechan Orthop* 4 H 3

Dahmen G & Meyer H (1965) Über die verschiedenen Methoden zur Arthrodese des oberen Sprunggelenkes *Arch orthop Unfallchir* 58 265

Fritsche H (1957) 40 Falle von Sprunggelenkarthrodesen von Gesichtspunkt der Sozialversicherung aus gesehen *Z Unfallmed Berufskr* 50 111

Guildal P & Sodemann T (1930) Result of 256 triarticular arthrodeses of the foot in sequelae of infantile paralysis *Acta orthop scand* 1 199

Hamsa, W R (1936) Panastragaloid arthrodesis A study of end results in eighty five cases *J Bone Jt Surg* 18 732

Jansen K (1962) Arthrodesis of the ankle joint *Acta orthop scand* 32 476

Kivilaaksо R Langenskiold A & Salenius P (1965) Results of TC and pantalar arthrodesis of the ankle joint in post traumatic conditions *Acta orthop scand* 36 339

Lasker W (1923) Spätresultate der Arthrodesenoperation nach Cramer zugleich ein Beitrag zur Frage der Knochentransplantation *Bruns Beitr klin Chir* 128 499

Liebolt F L (1939) Pantalar arthrodesis in poliomyelitis *Surgery* 6 31

Moore D C (1954) Sciatic and femoral nerve block *Clin orthop* 4 206

Ratliff A H C (1959) Compression arthrodesis of the ankle *J Bone Jt Surg* 41 B 524

Ropes M W Bennett G Cobb S Jacox R & Jessar R A (1959) Revision of diagnostic criteria for rheumatoid arthritis *Arthr rheum* 2 16

Steinbrocker O Traeger C H & Batterman R C (1949) Therapeutic criteria in rheumatoid arthritis *J amer med Ass* 140 659

Vahvanen V (1967) Johto ja intraosseaaliauestesian kayttomah lollisuudet reuma potilaiden ortopediassa *Duodecim (Helsinki)* 80 1075

Vahvanen V (1967) Rheumatoid arthritis in the pantalar joints A follow up study of triple arthrodesis on 292 adult feet *Acta orthop scand* Suppl 107

Vainio K (1956) The rheumatoid foot A clinical study with pathological and roentgenological comments *Ann chir gynaec Fenn* Suppl 1

Waugh T R Wagner J & Stinchfield F E (1965) An evaluation of pantalar arthrodesis a follow up study of one hundred and sixteen operations *J Bone Jt Surg* 47 A 1315

Acta orthop Scandinav 40 653–663 1969

Department R Section of Orthopaedic Surgery (Heads Ib Andersen and Preben Thestrup Andersen) Gentofte Hospital Copenhagen Denmark

FRACTURE OF THE SPINE

Follow up on a Material Treated by Early Mobilization

P Thestrup Andersen & Erik Horlyck

Received 14 xi 68

A fracture of a vertebral body occurs partly by pure compression as when falling on the feet but as a rule the compression is associated with hyperflexion more rarely lateral movement or hyperextension of the spine Depending upon the severity of the trauma there may be involvement of the disc posterior and anterior longitudinal ligaments the interspinal ligaments the articular processes and the arch—and this is where the risk of displacement of the fracture and cord lesion comes in

Unstable fractures are most often encountered in the cervical spine In *Koskinen & Nieminen's* (1967) material of 159 patients with fracture of the cervical spine 55 had neurological signs two thirds of whom had cord lesions

In the dorsolumbar spine unstable fractures and cord lesions are rare as may be seen also from our series But in *Griffith's* (1966) material of numerous severe traffic accidents cord lesions were present in almost 10 per cent

The stable fractures of the vertebral bodies in the dorsolumbar spine have been treated according to changing principles In the 20's and 30's the principles of Watson Jones Davis and Bohler predominated These principles were reduction with fixation of the spine in plaster in a hyperextended position for 2 or 3 months Early mobilization was used The plaster jacket was followed by a canvas back support for yet another 2 or 3 months

Gradually however there has been a modification of and a change in the attitude to the treatment as it was realized *firstly* that the reduction does not hold X ray follow up after some years showing renewed collapse (94 per cent recurrences in *Baab's* (1966) material

and in 21 out of *Savastona's* (1960) 25 patients) *secondly* that the results in the fractures affecting the dorsal spine which are very difficult to reduce are just as good as those in reduced case and *thirdly* that the late sequelae in the form of pain are not due to the compressed vertebra This change in the attitude is due partly to Magnus who already in the 30 s advocated bed rest never using reduction or canvas back support and later to Nicoll who in the 40 s recommended functional treatment consisting of bed rest for 2–3 weeks support under the back and simultaneous physical training in the form of extension exercises of the long back muscles He used this treatment in mild stable compression fractures without any attempt at reduction

Most subsequent authors have adopted Nicoll s principles but in many places hyperextension jackets or merely canvas back supports are still in use (*Baab* 1966 *Howorth* 1956 *Savastona & Pieri* 1960) although they delay rehabilitation of the back muscles and thus increase the duration of disability as also pointed out by *Nicoll* (1948)

Our series was treated exclusively by the principles of Nicoll and in the follow up study we tried to assess the primary results as well as the results at longer sight

THERAPEUTIC REGIME

In uncomplicated cases of spinal fracture we put the patient to bed with a veneer sheet beneath the mattress and administer analgesics of the acetylsalicylic acid group combined with codeine or caffeine

If there is no suspicion of cord lesion if we have the impression that the fracture is stable and if the posterior margin of the vertebral body is radiologically intact we start training of the back on the second day and soon after rolling in bed The physiotherapy follows the principle that the back should be kept extended during all movements and exercises Gradually as the exercises no longer cause pain they are rapidly replaced by new ones until complete mobilization

At discharge the patients are advised to continue doing the exercises at home or on an out patient basis in a physical medicine clinic until no pain remains The radiological findings were not routinely checked during the stay in hospital

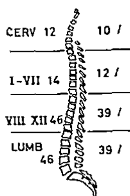


Figure 1 Distribution by site of 118 fractures in 104 patients

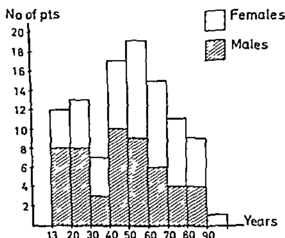


Figure 2 Age distribution curve.

PRESENT INVESTIGATION

During the period 1 January 1960 to 1 November 1967 a total of 113 patients with fracture of the spine were admitted to Surgical Department R of the Gentofte Hospital Copenhagen Primarily we excluded 9 diagnosed as sequelae to spinal fracture or suspicion of spinal fracture The former group had primarily been treated else where often by other principles In all cases diagnosed as only suspicion of spinal fracture it was not possible to confirm the dia gnosis at follow up

Figure 1 lists the localization of the fractures in the remaining 104 patients The dorsal spine is divided into an upper segment from the 1st–7th and a lower segment from the 8th–12th dorsal vertebra In the upper part there is great stability because of the thoracic cage (*Koslinen & Nieminen 1967*), and it is difficult to reduce these fractures The 104 patients had a total of 118 fractures 92 or 78 per cent affected the lower dorsal and lumbar spine with a distinct maximum at the 1st lumbar vertebra The cervical and upper dorsal spine were affected in 10 and 12 per cent respectively

The age distribution is presented in Figure 2 Fracture of the spine is a fairly common occurrence in elderly and aged persons due to senile osteoporosis (*Nicoll 1948*) In our series the sex ratio is equal

Table 1 104 patients with following types of fracture

Compression fractures of vertebral body	91
Fracture of vertebral body with avulsion	25
Isolated fracture of the transverse or spinous process	9
Fracture of arch	5
Dislocation	8

Table 1 gives the distribution by type of fracture It is apparent that by far the greater part of the fractures were compression fractures of the vertebral bodies In 23 out of 25 fractures of vertebral bodies with avulsion there was also compression fracture

Table 2 Cause of accident (104 patients)

	No of pts	%
Traffic accident	29	27
Fall from heights	37	36
Sporting accident	8	8
Diving in shallow water	1	1
Miscellanous	29	28

In Table 2 the causes of the injuries are listed Falls from heights the largest group of 37 patients or 36 per cent is a motley group comprising severe working accidents with falls from great heights as for instance from a scaffold a pylon or the like as well as typical home accidents with falls from kitchen table stool or down a stair case Traffic accidents were responsible in approximately one quarter of the cases Sporting accidents especially riding were to blame in

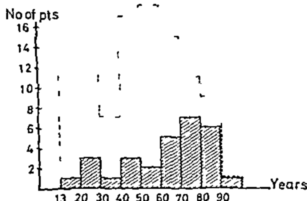


Figure 3 Age distribution for patients without adequate trauma (total of 29 patients)

8 per cent In 29 cases (28 per cent) there had been no adequate trauma In two cases these fractures occurred in patients on steroid medication and a young man of 23 had a spontaneous fracture of the spine Subsequent medical investigation however has given rise to a suspicion of hypercalciuria In the great majority of cases however the spinal fractures with a non adequate trauma were observed in elderly and aged subjects The role of senile osteoporosis is apparent from the age distribution curve on Figure 3 which shows a marked preponderance of aged persons as compared with the age distribution curve for the material as a whole (top of the Figure)

Table 3 Number of concomitant lesions (104 patients)

Craniocerebral injury	22
Chest injury	6
Abdominal injury	4
Renal injury	8
Injury to limbs	12

In 67 cases the spinal fracture was an isolated injury Table 3 lists the number and nature of complicating injuries Craniocerebral trauma predominates Renal injury was recorded in the presence of gross or microscopic haematuria Seven patients showed on the first days after the accident a state of subileus of a paralytic type

Among patients with fractures of the cervical spine there were 4 cases of permanent and 2 cases of transient pareses Paraesthesiae

and sensibility disturbances were permanent in 4 cases and transient in 2 Sphincter disturbances were not observed in patients with fractures of the cervical spine

Out of the 46 patients with fractures of the dorsal spine one patient had transient and one a permanent paralysis Two had transient and one permanent sphincter disturbances

Of the 46 patients with fractures of the lumbar spine two had transient and none permanent paralysis Two had transient and three permanent paraesthesia and one patient had transient and one permanent sphincter disturbances

Out of the 104 patients 13 had died at the time of follow up including two who succumbed to their spinal fracture The histories of these two patients will be briefly summarized below

Case record 1085/60 A 21 year old man admitted after having dived into shallow water Immediately after the accident he had felt remote and had experienced respiratory distress After admission he complained of weakness and paraesthesia in both arms X rays of the cervical spine showed compression fracture of the bodies of the 5th and 6th cervical vertebrae The posterior margins formed a posteriorly sharp angle on each other projecting into the cervical canal The patient was transferred to a neurosurgical department where he was treated by extension on the skull During his stay there he died of large emboli in the main branches of the pulmonary artery

Case record 1997/65 An 80 year old man was admitted after having fallen (3 m) from a pear tree On admission there was amnesia for the accident. Flaccid pareses of both legs and a loose spinal fracture at the 12th dorsal vertebra X rays revealed a compression fracture of the 12th dorsal vertebra with slight lateral displacement and some diastasis between the spinous processes He was transferred to a neurosurgical department and later to the Physical Medicine Hospital at Hornbæk. He remained a wheelchair patient and was incontinent for urine until he died of decubitus and septicaemia 6 months after the accident

Sixteen patients could not be traced Thus the follow up comprised 75 patients The follow up periods are listed in Table 4

Table 4 Follow up period

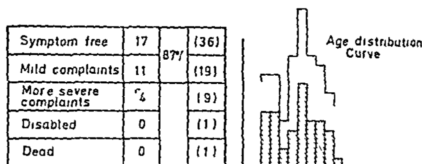
5 mths	1
6–12 mths	9
1–2 yrs	10
2–4 yrs	27
4–8 yrs	28

The follow up study aimed at elucidating the results of individualized early mobilization *in the treatment of fractures affecting the* vertebral bodies of the dorsal and lumbar spine This applied to a total of 86 patients only 2 of whom had isolated avulsion at the anterior margin of the vertebral body

Table 5 Fractures of the vertebral body of the dorsolumbar spine Primary results (86 cases)

Bed rest		Physiotherapy		Period off work	
<1 wk	12	<2 wks	21	<1 mth	15
1 2 wks	39	2–4 wks	30	1–2 mths	32
2–4 wks	30	4–8 wks	16	2–3 mths	9
>4 wks	4	>8 wks	1[illegible]	>3 mths	10

Primary results (Table 5) The figure gives the number of weeks in bed the duration of the physiotherapy and the period of work in cases where these factors are known 59 per cent had been immobilized *for less than 2 weeks Among 66 patients with compression fracture* of the dorsolumbar spine included in the follow up 15 had returned to work in less than one month and a total of 47 patients (71 per cent) in less than 2 months Many patients had no physiotherapy after discharge but 16 continued for up to 8 weeks and 12 for more than 8 weeks after the accident The symptoms and signs at follow up in 66 patients with compression fracture of the dorso lumbar spine were *backache episodes of sciatica and back fatigue* tenderness of back muscles restricted mobility and a positive Lasegue (Table 6) back fatigue and backache being the predominant symptoms in half and one third respectively The total assessment of subjective complaints and working ability is given in the same Table At the time of follow up 36 patients were entirely symptom free and 19 had slight complaints These 19 patients had a normal working ability but had *intermittent vertebral symptoms* especially in the form of fatigue It was a characteristic finding that these symptoms would occur after strain beyond the daily routine In view of their working ability and general condition in daily life they must be considered as cured although the ability of the back to tolerate strain is reduced Nine patients had more severe complaints These patients had almost daily symptoms in the form of backache or back fatigue Some of them but far from all have had *intermittent* but invariably short periods



Symptom free	17	87%	(36)
Mild complaints	11		(19)
More severe complaints	4		(9)
Disabled	0		(1)
Dead	0		(1)

Figure 4 Fractures of the vertebral body of the dorso lumbar spine immobilized for less than 2 weeks Late results 32 (42) cases

of illness A few have undergone rehabilitation changing from heavy to lighter work A few female patients had given up their employment One patient is disabled and one (Case record 1997/65) has died

Table 6 Fractures of the vertebral body of the dorsolumbar spine Late results 66 (86) cases

Symptom free	36	83 %	Backache	21
Mild complaints	19		Episodes of sciatica	10
More severe complaints	9		Back fatique	31
Disabled	1		Tenderness of back muscles	12
Dead	1		Restricted mobility	11
			Positive lasegue	4

Thirty two patients of the follow up material who had been immobilized for less than 2 weeks and who had no history of other spinal disorders were considered separately (Figure 4) Out of these patients 87 per cent were symptom free or had mild complaints although 4 had more severe complaints This is somewhat better than for the group as a whole (Table 6) The age distribution curve shows that the patients were immobilized without regard to age Out of the 4 patients with more severe complaints 3 had been followed for less than a year By way of comparison it may be mentioned that out of 8 patients followed for less than a year 3 had severe complaints as compared with 6 out of 46 followed for more than 2 years One of the 3 patients moreover has a postulated compensation case which clearly influences the complaints The fourth patient has been followed for 18 months This patient a young man who plays football without complaints changed his occupation from T V mechanic to precision mechanic because of his back In retrospect on the basis of our

criteria there does not seem to have been in any of these 4 cases a reason for longer lasting immobilization Among the remaining 5 patients of the total group with more severe complaints 3 have had neurological signs The disabled patient had a severe fracture of the dorsal spine with a gibbus He had pre-existing abnormal kyphosis and spondylotic changes

Table 7 Fractures of the vertebral bodies of the dorsolumbar spine Radiological sequelae (53 X rayed pts)

Kyphosis	Gibbus	Scoliosis	Block vertebral	Second narrow of disc	Second spondyl	Visible seq
18	6	9	2	12	25	53
Fractures of the bodies of the dorsolumbar spine immobilized for less than 2 weeks (26 X rayed pts)						
10	2	3		6	7	26

At follow up X rays of the spine were obtained in 53 of the patients with fracture of a vertebral body The films showed in all cases radiological sequelae of the fracture Indeed this was to be expected as no form of reduction had been performed In addition there was in some cases abnormal kyphosis gibbus and scoliosis block vertebrae secondary narrowing of the disc and secondary spondylosis (Table 7) Gibbus scoliosis and secondary spondylosis were rare among patients immobilized for less than two weeks The late results in patients with radiological sequelae when disregarding gibbus and scoliosis do not appear to be poorer than in the total series

Moreover it was found that patients with fairly heavy work (a total of 23) have a somewhat poorer prognosis 80 per cent being symptom free or having mild complaints as compared with 92 per cent of 40 patients with lighter work Patients with a heavier type of work have been off work longer 50 per cent having returned to work within 2 months as compared with 86 per cent of the patients with lighter manual work

Patients in the age group 40–59 years (20 patients) were off work longer than those of the age group 13–30 (17 patients) 5 of the former group being off work for more than 3 months as compared with one patient of the young group Four patients of the older group had severe complaints and one was disabled as compared with 2 patients with severe complaints in the age group 13–30 years

DISCUSSION

Our results i e an average cure rate of 83 per cent must be considered satisfactory and corresponds to the results obtained by others (*Hansen & Villumsen* 1959 *Savastona & Pierik* 1960) No better results can be obtained by temporary application of a hyperextension jacket (*Baab* 1966) or by surgical spinal fusion (*Howorth* 1956) The final result cannot be assessed until 2 years have elapsed (*Savastona & Pierik* 1960) as is also apparent from our series Rather than advising a canvas back support or belittling the patient s complaints one should refer them for physiotherapy, possibly preceded by massage and heating as emphasized *inter alios*, by *Nicoll* 1948

Traffic accidents will go on making up an ever increasing part of the causes in our series 25 per cent but in *Griffith et al s* (1966) almost 50 per cent Their material was from an area with heavy and fast traffic *Griffith et al* found the most common site of the fracture to be the 6th dorsal vertebra, and this applied especially to young patients who often had severe concomitant injuries

The radiological changes of secondary spondylosis disc degeneration and kyphosis found at follow up did not entail poorer results but scoliosis and gibbus formation showed perhaps somewhat poorer results than the average However the numbers involved are too small for statistical analysis

From our material it is clearly apparent that frequently the duration of bed rest may be restricted to less than 2 weeks without compromising the late result From talks with the patients at follow up it seems beyond doubt that the quality of the physiotherapy and in particular the patients understanding of its importance and of observing it daily through many months is the alpha and omega of the treatment as is also emphasized by Nicoll and by Watson Jones

SUMMARY

A material of 104 patients with fracture of the spine is submitted Out of these patients 86 had fractures localized to the bodies of the dorso lumbar spine The treatment was individualized early mobilization and physiotherapy The primary results as well as the late results on the basis of a follow up study are reported

ACKNOWLEDGEMENT

We acknowledge our indebtedness to *Mogens Jorgensen* M.D Head of the Department of Medical Computing Gentofte Hospital, for help in the statistical calculations which were done on an IBM 1800 computer

REFERENCES

Andreassen M & Dahl Iversen E. (1942) Behandlingen af fraktura corp vertebrae en indledning til diskussion. *Nord Med* 16 2939

Baab, O D (1966) Fractures of the dorsal and lumbar spine. *Clin Orthop* 49 195–200

Griffith, H. B., Gleave J R. W & Taylor R. G (1966) Changing patterns of fracture in the dorsal and lumbar spine *Brit med J* 1 891–894.

Hansen E. C & Villumsen A. L. (1959) Fraktura corp columnae *Nord Med* 61 847

Howorth M B (1956) Fracture of the spine *Amer J Surg* 92 573–592

Koskinen E V S & Nieminen R. (1967) Fractures and dislocations of the cervical spine. *Int Surg* 47 (2) 472-485

Magnus G (1929) Die behandlung und begutachtung von wirbelbruchen *Munch med Wsch* 76 527–530

Magnus G (1938) Zur behandlung der wirbelbruche *Arch Klin Chir* 191 547–556

Nelson H (1958) Functional treatment of compression fractures of the spine *J med Ass Ga* 47 3–9

Nicoll, E. A (1953) Injuries to the back. *Brit med J* 1 879–880 928–929

Nicoll E. A (1948) Redevelopment of the musclefunction *J Bone Jt Surg* 30 B 392

Savastona, A A & Pierik, J G (1960) Traumatic compression fractures of the dorsolumbar portion of the spine. *J int Coll Surg* 34 93–101

Watson-Jones R. (1955) Fractures and joint injuries. Vol II 4th ed Williams & Wilkins Co Baltimore

Wong P C. N (1966) Vertebral column and os calcis fracture patterns in a confined community *Acta orth scand* 37 357–366

Acta orthop Scandinav 40 664-688 1969

PROCEEDINGS OF THE NORDISK ORTOPEDISK FORENINGS 34th ASSEMBLY IN NORWAY JUNE 1968

The meeting of the Scandinavian Orthopaedic Association was held in Sandefjord under the Presidency of Henrich Nissen Lie

TRAUMATIC LESIONS OF THE SPINE AND PELVIS

Chairman Arnt Jakobsen (Oslo Norway)

FRACTURE OF THE SPINE

Hans Rostad Kaare Solheim Per Siewers & Mons Lie (Oslo Norway)

In the 10 year period 1952-61 inclusive 1223 patients (556 men and 667 women) with fracture of the spine were admitted to the Surgical and Neurosurgical Depart

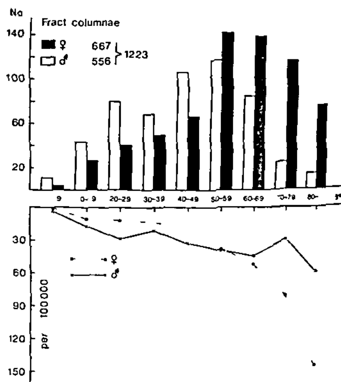


Figure 1 Fracture of the spine Oslo 1952-61 Upper part age and sex distribution Lower part number of patients with fracture of the spine per 100 000 inhabitants in the different age groups (calculated on an estimated average population in Oslo as of 1 January 1956)

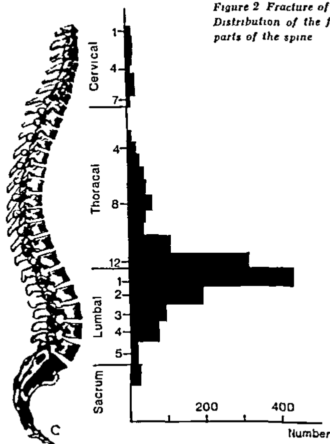


Figure 2 Fracture of the spine, Oslo 1955–61 Distribution of the fracture in the different parts of the spine

ments Aker and Ulle Ål Hospitals Oslo This is the majority of such patients in Oslo in this period *The majority of the patients were 50–60 years of age* There was an increase in incidence after the age of 60

In Th_{11} L_3 there were 1355 fractures, i e 64 per cent of the altogether 2075 fractures of the spine

Falls in and out of-doors were the causes of injury in 55 per cent of the cases

In 1119 patients treatment was bed rest and exercises, reposition and plaster of paris were used in 34 patients and 53 were operated upon

The 57 patients with nerve lesions (4.5 per cent) were followed up clinically and *roentgenologically after an observation time of 7–16 years Of these 23 had com*plete lesion of the spinal cord and 34 partial lesion Nine patients with complete lesion of the cervical and thoracal spinal cord were dead, 7 of whom died in connection with the accident or shortly after Of 14 patients with complete lesion in the lumbar spinal cord 11 were alive, 6 of whom were fully employed

Of the 34 patients with partial lesions, 1? were without symptoms 7 had slight paresis and were fully employed 5 were more or less crippled

FRACTURES OF THE SPINE WITH CORD LESIONS

C Blikra & R Ringkjøb (Oslo Norway)

In a series of 100 patients with fracture of the spine with cord lesion (55 cervical, 24 dorsal and 21 lumbar) traffic accident was the most frequent cause in cervical injuries

Lack of free airways immediately after the accident or during transportation led to several complications and some early deaths

Eleven patients died before admission to hospital another 15 within the first weeks In the rest early laminectomy was performed in 31 patients Of 18 patients with complete paraplegia or quadriplegia improvement was demonstrated in only 2 both with conus cauda lesions Of 13 patients with incomplete transverse lesions 5 were improved Three of these were operated upon because of increasing neurological signs and 1 because spontaneous improvement had ceased

Laminectomy or early operative spinal fusion did not influence the frequency of early complications from the respiratory or the urinary tract or of decubital ulcers

Adequate first aid at the scene of the accident including provisions for open airways and careful lifting and transportation may improve the prognosis of traumatic paraplegia Skull traction should be applied as early as possible in cervical lesions Laminectomy is indicated mainly in patients with increasing neurological deficit. Avoidance of complications depends on special nursing

FRACTURE OF THE SPINE TREATED BY INDIVIDUAL EARLY MOBILIZATION AN EIGHT YEAR FOLLOW UP STUDY

P Thestrup Andersen (Gentofte Denmark)

The authors conclude that early mobilization is an effective and safe procedure in dorso lumbar corporal fractures when spinal cord lesions or instability are absent The treatment should be followed up by intensive physical re training.

To be published in Acta Orthopaedica Scandinavica.

A MODIFIED SO CALLED HALO SPLINT FOR THE EARLY MOBILIZATION OF PATIENTS WITH CERVICAL SPINE LESIONS

Håkan Brattström Mark Blomberg & Urban Pontén (Lund Sweden)

The so-called halo splint, designed in and described from the Rancho Los Amigos Hospital, Los Angeles has come into wide use in the Anglo Saxon countries for traction and fixation in traumatic lesions of the cervical spine

This apparatus has great advantages primarily that of allowing an almost immediate mobilization of the patient Drawbacks It is difficult to apply does not permit detailed X rays no myelography or tomography moreover it is not possible to grade the force of traction The authors reported on a modified apparatus in which these drawbacks have been largely eliminated This apparatus will be described in detail elsewhere

FOLLOW UP ON A GROUP OF PATIENTS WITH PARA AND QUADRIPLEGIA

Bodil Eskesen (Hornbæk, Denmark)

During the period 1954–1967 a total of 410 patients with acquired para or quadriplegia have been treated in the Physical Therapy and Rehabilitation Hospital, Hornbæk Denmark. Most of the cases were of traumatic origin and no progressing diseases are included. The majority of the patients were admitted 1–3 months after the injury was sustained transferred from neurosurgical and orthopaedic departments on Zealand and Funen (population 2.6 millions)

The follow up study was carried out in 1967 and comprised patients with complete transverse lesion of the cord—45 with paraplegia (traumatic in 44 cases) with a minimum follow up period of 2 years and 100 with paraplegia (traumatic in 78 cases) with a minimum follow up period of 1 year

75 per cent of the patients were in the hospital for less than 12 months, 25 per cent for 12–24 months the rehabilitation being delayed particularly by decubitus ulcers or by urinary complications

Decubitus ulcers were present in 66 out of 145 at first admission but the incidence has been decreasing during recent years. After their final discharge about 50 per cent of the patients developed decubitus

Complications from the urinary tract Bladder stones in some 50 per cent, nephrolithiasis in 5 and urethral fistula in 8 out of the 145 patients All cases of urolithiasis were treated by operation as soon as possible

83 patients with paraplegia and 22 with quadriplegia were discharged primarily to their own homes and later 5 paraplegics and 6 quadriplegics could be discharged from nursing homes to their own homes

Medical rehabilitation to independence in the activities of daily living was obtained in 76 patients with paraplegia whereas 5 children 7 elderly patients and 5 patients with complications are in need of help (7 have died, 6 of cutaneous or urinary complications)

Out of 32 patients with quadriplegia 8 have acquired independence in the activities of daily living—all under 32 years of age This group includes one patient with a complete transverse lesion distally to the 6th cervical segment. 7 need some assistance and 17 are completely dependent (13 have died, 7 of cutaneous and urinary complications)

Vocational rehabilitation Out of 93 surviving paraplegics 56 are employed or being trained for work Ten have given up working because of complications, 27 have not been working mainly because of advanced age

Out of 32 quadriplegics 16 are employed or being trained for work although not all of them are independent in the activities of daily living The remaining 16 have no work

This follow up study supports the view that this category of patients should be collected and treated together in a few departments where the entire staff—doctors nurses and other personnel as well as medical advisers can work as a team and can gather experience of the paraplegics problems.

DISCUSSION

Erik Moberg (Gothenburg Sweden)

So far little has been mentioned concerning the stability in so-called fractures of the vertebral bodies It must be borne in mind that although the skeletal damage certainly predominates radiologically the injuries not infrequently affect mainly the intervertebral disc and ligaments in particular the interspinous ligament and the strong anterior longitudinal ligament This has been pointed out by *inter alios* Nicoll In such cases the fracture merely indicates the level of the injury

Clinically the lesion is often easily palpable There may be considerable tenderness between the spinous processes of the vertebrae where the ligament has ruptured If the patient is placed prone on a pillow and the injury is at the dorso lumbar junction direct pressure by the thumbs over the spinous processes may reveal abnormal mobility and pain due to the instability In such cases I primarily perform short bone graft fusion and the results have been good This diagnostic technique is often omitted and frequently the radiologist does not visualize the spinous processes and thus cannot demonstrate the increased distance

A Nachemson (Gothenburg Sweden)

Due to increasing compression of a vertebral body the mobilization of some paraplegics will bring about disturbing gibbosity The spinous processes may sometimes cause erosion of the skin and instability and pain may also follow These problem patients are presented to the orthopaedic surgeons by the rehabilitation people

The Harrington distraction rods for correction of scoliotic spines may also be used for the correction of increasing kyphosis One patient (a 50 year old male) is presented in which increasing angulation of the spine at the Th 12 level was reduced from 45 to 20 by the use of one Harrington distraction rod on each side of the spinous processes anchored with hooks to the laminae of Th 10 and L 2 respectively Bilateral lateral fusion was performed in the same stage and the patient was allowed to get up and start exercises two months after surgery No plaster bed was used After 4 months the spine appeared to be stable and walking exercises were started

This procedure offers a relatively simple solution for patients with unstable kyphotic spines after fractures of vertebral bodies With these rods correction can be achieved and at the same time the fixation is stable enough to allow adequate skin-care turning in bed etc which is of importance for paraplegics

FRACTURE OF THE PELVIS

Kaare Solheim Hans Rostad Per Stewers & Mons Lie (Oslo Norway)

In 1952–61 inclusive 524 patients with fracture of the pelvis were treated at the Surgical Departments of Ullevål and Aker Hospitals This figure constitutes the majority of patients with this type of injury in Oslo (450 000 inhabitants) during that period There were 276 women and 248 men in the series Women outnumbered men in the age groups over 70 years and the incidence rose sharply in the older age groups Falls indoors and outdoors were the commonest cause (about 50

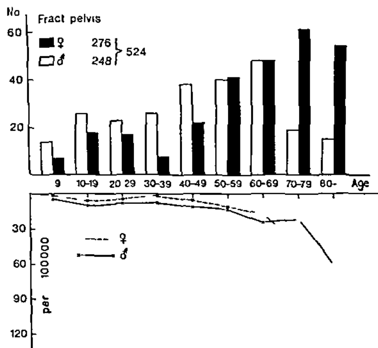


Figure 1 Fracture of the pelvis Oslo 1952–61 Upper part Age and sex distribution Lower part Number of patients with pelvic fractures per 100 000 inhabitants in the different age groups (calculated on an estimated average population in Oslo as of 1 January 1956)

per cent) and traffic accidents were the cause in one third of the patients with a marked increase in the later years Multiple injuries were therefore common and were registered in one third of the patients

The majority of the patients were treated conservatively Operation and traction treatment were carried out in only 20 and 39 patients respectively The period of bed rest was reduced in the course of time one fourth of the patients being confined to bed for less than a week

Complications from the pelvic fracture were uncommon (rupture of urethra or urinary bladder in 20 patients nerve injury (ischiadicus) in 6 patients and severe hemorrhage in 6 patients (patients needing 2 pints of blood or more to stabilize their vital signs))

23 patients died. Of these 10 died from multiple injuries, two from hemorrhage five from fat embolism and seven from bronchopneumonia.

Follow up was carried out on patients with ruptured symphysis (17 patients) and fractures involving the acetabulum (9 patients) Except for central luxation fractures, the clinical and X ray results were found to be good in the majority of the patients Patients with se ere displacement of the acetabulum had bad clinical results and severe arthrosis Operative treatment is recommended as the treatment of choice in these patients.

FRACTURA PELVIS AND FRACTURA ACETABULI

Olaf Holter (Tønsberg Norway)

During the years 1955–1964 88 patients (40 women 48 men) with pelvic injuries were admitted to the Surgical Department, Vestfold Sentralsykehus. The injuries were classified as fractura pelvis in 67 patients and fractura acetabuli in 21 Fifty per cent of all the fractures arose from traffic injuries. Approximately 35 per cent of the patients had multiple lesions of these, *ca.* 85 per cent were caused by traffic injuries. Most of the accompanying injuries were to the head or extremities—in 4 cases there were injuries to the urinary bladder and/or urethra.

In a follow up study in which 48 of the 67 patients with fractura pelvis replied to a questionnaire, 40 reported complete recovery and 8 complained of back pain, especially while walking Two women had required sectio cesarea.

Of the 21 cases of fractura acetabuli 6 showed fissures—the 5 patients with fissure who replied to the questionnaire claimed complete recovery

Seven of the patients with central acetabular fracture were followed up with a clinical and roentgenological examination as were 2 patients with dorsal dis location These 9 patients had pain and restricted movement of the hip, as well as back pain. Three of these 9 were operated upon one according to the method of Smith Pettersen (cup arthroplasty) one by arthrodesis (primary), and one by repositioning the luxation and fixing the posterior fragment by a screw The remaining patients were treated by traction This treatment did not have any effect on the position of the fragments.

In addition to restricted movement of the hip joint, painful movements, and back pain the patients with fractura acetabuli also complained of pain e pecially in the sacroiliacal and sacrospinal muscles. Four showed scoliosis and one necrosis of the femoral caput. All these patients had shortening of the limb varying from 1 5 to 3 5 cm and in 5 cases a Trendelenburg positive deformation

The chief aims of treatment in cases of central acetabular fracture must be to achieve a stable joint to avoid deformity of the pelvis, and to avoid shortening of the limb The joint must, therefore be reconstructed.

DISCUSSION

Mac Fellander (Stockholm, Sweden)

As regards fractures of the pelvis, an exact classification is important. Different types of fracture for instance double vertical fractures and central *dislocation* fractures present special problems

A series of cases of pelvic fractures from the Stockholm region has been presented by Lars Raf my former co worker (Acta chir scand *131* 298, 1966) It comprises 101 patients over the period 1952–1963 His observations agree on the whole with those reported here by Slatis and Huittinen The mortality rate was 12 per cent as shock due to blood loss was the cause of death in half the cases, increased attention should be given to this complication. Follow up examination of 65 patients showed a high incidence of considerable back trouble in the cases in which the fracture ran through the sacrum or into the sacroiliac joint. In the treatment of such fractures of the pelvic girdle with cranial dislocation we propose

reduction with femoral traction and subsequent fusion in the sacroiliac joint A case of such treatment was demonstrated

A series of 50 patients with central dislocation of the hip from the Stockholm region over the period 1954–1963 has also been analysed (to be published by Gothlin & Hindmarsh) The prognosis depends upon the fracture involvement If the fracture involves the inner wall the prognosis is favourable If it involves the upper dome the prognosis is poorer and depends upon the degree of reduction that can be achieved by traction treatment and upon the condition of the acetabular roof One third of the total number of patients were more or less disabled Four patients with severe injuries of the upper dome were treated by cup arthroplasty since the prognosis was judged as very poor In three of these cases the results were very good in the fourth in which the operation was made about a year and a half after the injury the result was less satisfactory The ideal time for this operation would be about six weeks after the injury when the fractures in the pelvic floor begin to unite This reconstructive operation is an alternative to the technically difficult method of open reduction and osteosynthesis which has been described by Judet and his co workers and, at this Congress by Olerud

Erik Moberg (Gothenburg Sweden)

Symphysiolysis with or without other damage to the pelvis may be successfully treated surgically The simplest and safest way is to pull the symphysis together by a wire loop through the obturator foramina It is not advisable to use a wire through a drill hole or plate and screws, as the skeletal structure is not suited for such osteosyntheses which are apt to fail The cortex in the obturator foramina is sufficiently resistant. The procedure is simple and the patients may be mobilized in a week or two The common swelling of the legs due to accumulation of fluid around the pelvic lesions, soon disappears

HAEMATOGENOUS OSTEOMYELITIS—PATHOLOGY

Eivind Myhre (Oslo Norway)

Most cases of osteomyelitis arise in the metaphysis due to the vascular arrangement in bone From the age of one year the epiphysial cartilage forms a vascular barrier which is one of the reasons why osteomyelitis behaves differently in various age groups. Some characteristics in the development of untreated acute osteomyelitis are shown in Table 1

Chronic osteomyelitis of the secondary type develops either from an acute osteomyelitis or is due to trauma. The primary type manifests itself as a Brodie abscess, sometimes as plasma cell osteomyelitis or very rarely as Carré's sclerosing osteomyelitis

The histological features of acute infection are characterized by hyperaemia oedema, and leukocytic infiltration The suppurative reaction with the formation of pus *reveals a tendency to expand in both directions in the bone marrow* Ischaemia occurs because of thrombotic processes in the neighbouring vessels and because oedema and pus expands through the cortex to the periosteum which is raised from the cortex thus disrupting the vascular connections Ischaemia leads to necrosis which again leads to the formation of sequestra

Table 1 Acute haematogenous osteomyelitis at different ages

	Infants (under 1 yr)	Children	Adults (over 16 yr)
Localization	Meta- and epiphysis	Metaphysis	Diaphysis
Multiple foci	Rather frequent	Rare	–
Spread	Subperiostal epiphysis and joint	Diaphysis	Extraperiostal epiphysis and joint
Sequestrum	Rare	Frequent	Rare
Fistula	Rare	Rather frequent	Frequent
Involucrum formation	Strong	Moderate	Weak

The histological changes of chronic osteomyelitis are characterized by a zonal arrangement.

Antibiotic treatment has greatly changed the course of the disease and thereby also the pathological anatomical picture

RADIOLOGICAL FINDINGS IN OSTEOMYELITIS

Sigurd Eek (Oslo Norway)

For therapeutic reason the diagnosis of *acute* osteomyelitis should be made by the clinician *before* radiological changes have appeared in the soft tissues and bones It is thus the primary task of the radiologist to support or weaken the clinical suspicion of osteomyelitis This cannot be done until swelling of the soft tissues has appeared with increased outlines of the lymphatics and obliteration of the muscle contour against the subcutaneous fat A *definite* radiological diagnosis cannot be made until 1–3 weeks have elapsed and the osseous changes have become manifest At this stage sufficient treatment should have been instituted long previously

The task of the radiologist in *chronic* osteomyelitis is well known and no major technical or diagnostic methods have been added in recent years Therefore now as in the past the radiologist must be familiar with the diagnostic differential diagnostic and developmental problems of the disease and he must still be extremely reserved in making prognostic statements on the basis of the X ray findings in chronic osteomyelitis

ACUTE HAEMATOGENOUS OSTEOMYELITIS IN A 5 YEAR MATERIAL

Henrik Hagelsteen (Oslo Norway)

During the period 1963–1967 24 children with acute haematogenous osteomyelitis (0 24 per cent of all admitted patients) were treated 12 boys and 12 girls age range 0–14 years 9 were under 1 year of age

The most common site of the disease was in the metaphyses of the long bones. In 5 cases the spine was affected all 5 patients were 2–5 years.

The temperature on admission was below 37.5 C in half the cases

A highly increased ESR was a constant and characteristic early sign

Leukocytosis was inconstant and uncharacteristic.

A positive blood culture was found in only 2 cases (*Staphylococcus aureus*) but a number of the patients had received chemotherapy prior to admission.

The therapeutic principle was early institution of intensive chemotherapy continued for 6 weeks after the acute symptoms have subsided. In many cases the affected limb was fixed or a plaster cast used in cases of spondylitis

Children who fix a limb or the back because of pain and have highly increased ESR and possibly elevated temperature should be treated as cases of acute haematogenous osteomyelitis until another diagnosis has been made In that case the prognosis is favourable

OSTEOMYELITIS IN A SURGICAL DEPARTMENT

Rolf Hagen (Oslo Norway)

During the years 1957–66 21 acute and 28 chronic cases of osteomyelitis were treated in Department III Ullevål hospital.

Positive roentgenograms and bacteriological findings were demonstrated in respectively 18 and 8 patients with acute osteomyelitis Penicillin resistant staphylococci were cultured in 7 of these 8 cases Eleven conservatively treated patients disclosed symptoms of less than 5 days duration whereas 7 operated presented a longer history On follow up examination 4 patients with osteomyelitis of the femur showed lengthening up to 2 5 cm

The chronic infections originated from acute osteomyelitis in 11 postoperative infections in 9 and non operated compound fracture in 8 cases Among 129 conservatively treated compound fractures of tibia and femur were found 6 osteomyelitic infections, but none after osteosynthesis of 40 corresponding compound fractures. After osteosynthesis of 190 closed femoral fractures were found 4 cases

Table 1 Frequency of osteomyelitis after compound fractures and osteosyntheses Department III Ullevål Hospital 1957–66

	%
Compound fractures without osteosynthesis	4.5
Compound fractures with osteosynthesis	0
Osteosynthesis of closed fractures	0 5

Table 2 Follow-up study of chronic osteomyelitis Department III Ullevål Hospital

	No of patients
Healed	11
Defect healed	10
Active fistulating	2
Dead (of other causes)	5

Table 1 Acute haematogenous osteomyelitis at different ages

	Infants (under 1 yr)	Children	Adults (over 16 yr)
Localization	Meta and epiphysis	Metaphysis	Diaphysis
Multiple foci	Rather frequent	Rare	–
Spread	Subperiostal epiphysis and joint	Diaphysis	Extraperiostal epiphysis and joint
Sequestrum	Rare	Frequent	Rare
Fistula	Rare	Rather frequent	Frequent
Involucrum formation	Strong	Moderate	Weak

The histological changes of chronic osteomyelitis are characterized by a zonal arrangement.

Antibiotic treatment has greatly changed the course of the disease and thereby also the pathological anatomical picture

RADIOLOGICAL FINDINGS IN OSTEOMYELITIS

Sigurd Eek (Oslo Norway)

For therapeutic reason the diagnosis of *acute* osteomyelitis should be made by the clinician *before* radiological changes have appeared in the soft tissues and bones It is thus the primary task of the radiologist to support or weaken the clinical suspicion of osteomyelitis This cannot be done until swelling of the soft tissues has appeared with increased outlines of the lymphatics and obliteration of the muscle contour against the subcutaneous fat A *definite* radiological diagnosis cannot be made until 1–3 weeks have elapsed and the osseous changes have become manifest At this stage sufficient treatment should have been instituted long previously

The task of the radiologist in *chronic* osteomyelitis is well known and no major technical or diagnostic methods have been added in recent years Therefore now as in the past the radiologist must be familiar with the diagnostic differential diagnostic and developmental problems of the disease and he must still be extremely reserved in making prognostic statements on the basis of the X ray findings in chronic osteomyelitis

ACUTE HAEMATOGENOUS OSTEOMYELITIS IN A 5 YEAR MATERIAL

Henrik Hagelsteen (Oslo Norway)

During the period 1963–1967 24 children with acute haematogenous osteomyelitis (0 24 per cent of all admitted patients) were treated 12 boys and 12 girls, age range 0–14 years 9 were under 1 year of age

Martina Hansens Hospital has tried lincocin for a little more than a year in the treatment of 20 cases of chronic osteomyelitis. This observation time is too short for a final evaluation but out of 16 patients with lincocin sensitive microbes, 7 should so far be listed as cured and 6 as improved. We thus feel there is a reason for continued use of lincocin in patients with chronic osteomyelitis due to lincocin sensitive microbes.

Our experience is that the treatment should continue at least 5 weeks after the sinus has closed and possibly for a much longer period. In 5 patients who stopped within 4 weeks after the sinus closed there were 4 recurrences whereas in 7 patients who continued for 5 weeks or longer the infection has not recurred during a 6–10 months observation period.

EXPERIENCES WITH FUCIDIN IN THE TREATMENT OF OSTEOMYELITIS

Jan A Pahle (Oslo, Norway)

A material of 30 patients, mean age 44.6 years with chronic osteomyelitis was examined in order to assess the penetration and bacteriostatic effect of Fucidin in avascular sequestra, poorly vascularized bone and soft tissue and in pus. All patients had long standing processes with draining sinus or deep abscess, several repeatedly *operated upon. Duration of the disease 64 years to 2 months. Staphylococcus aureus* verified in 29 patients. The importance of accurate bacteriology in material from the depths of the sinuses was confirmed. I.C. 50 was established in some cases. The sequestra and other tissue samples were taken in [illegible] cases with use of a tourniquet in order to avoid false increase of the concentration by admixture of blood. The sequestra were cut down so that the Fucidin concentration was measured in the central part. Serum concentration after a daily dosage of 3 or 2 g Fucidin after a minimum of 8 days preoperative treatment varied between 15 and 210 μg/ml, the samples taken during the operation 10 hours after the last dosage. In poorly vascularized tissue a concentration of 21–59 μg/g was found. In pus 6–61 μg/ml. In bone tissue with some preserved vascularization values between 1.5 and 54 μg/g. In 3 histologically verified sequestra values of 2.6, 41 and 56 μg/g were found. The values were > I.C. 50 in these 3 cases. In 2 groups of the material the penetration of semi synthetic penicillins was examined simultaneously. Penicillin concentration was found to be only 20–50 per cent of that of Fucidin with large daily variations. The morning concentration of semi synthetic penicillins was → 0 against up to 117 μg Fucidin/g tissue. In poorly vascularized tissue a concentration of Fucidin 10 times higher than that of semi synthetic penicillins was found on an average. The observation time is too short (2 years) to permit conclusions about the lasting effect although the immediate results were very satisfactory.

PYOGENIC (NON SPECIFIC) BONE INFECTIONS BACTERIOLOGICAL VIEWS

Arne Lystad (Oslo, Norway)

The commonest causal organism in osteomyelitis is *Staphylococcus aureus*. The increasing occurrence of staphylococci resistant to penicillin G and other antibiotics in common use is a problem.

The pathogenic capacity of staphylococci is the combined effect of their ability to produce extracellular substances such as enzymes and toxins together with the

invasive properties of the strains In addition staphylococci are common members of the normal flora and they are also found regularly in human environments. Penicillin resistant staphylococci from clinical infections always produce an inducible enzyme penicillinase Resistance to some other antibiotics can be transmitted among staphylococci by transducing bacteriophages

Early diagnosis and use of the correct antibiotic are essential for the proper treatment of acute osteomyelitis The drug of choice should be bactericidal and should have a good action against penicillinase-producing staphylococci

Antibiotic treatment of chronic osteomyelitis must always be based on proper bacteriological investigations including sensitivity tests

Chronic osteomyelitis can be prevented by early and correct treatment of acute osteomyelitis and by proper care of surgical wounds and fractures The incidence of infection is related to the initial care of the wound and therefore initial decontamination of the wound is vital Prophylactic use of antibiotics is not indicated.

ORTHOPAEDIC INFECTIONS DURING A 5 YEAR PERIOD

Patient material *Lars Lindberg* (Malmo Sweden)

During 1963–1967 a prospective investigation was made of all infected orthopaedic patients at the Department of Orthopaedic Surgery in Malmo 200 men and 1 3 women Data concerning the course of the infections including the sedimentation rate ASTa CRP wound healing and bacteriology were registered along with the therapy (operation antibiotics etc)

The age distribution of the infected patients was found to be the same as that of the non infected patients 189 infections were postoperative 88 traumatic 47 haematogenous 6 caused by joint injections The origin of the remaining infections was doubtful 27 per cent of all infections were localized to the hip region 10 per cent to fractures (except fractures in the hip region) 11 per cent to joints, the remainder had varying localizations The duration of high serological values, of fistulation and of other signs of infection was tabulated and the duration of treatment in hospital and of treatment with antibiotics was discussed

Bacteriology *Carl Ericson* (Malmo Sweden)

Staphylococcus aureus was the dominating species although it could not be isolated from a few patients

Of more than 900 positive cultures staphylococci were isolated in 39 per cent coagulase negative taphylococci and enterobacteria each in about 18 per cent, *Pseudomonas* in 9 per cent Mixed cultures occurred in 33 per cent.

The possible aetiological significance of the bacteriological findings was discussed.

In 19 3 50 per cent of the *Staphylococcus aureus* strains belonged to endemic hospital types In 1967 this number had been reduced to about °0 per cent. From the phage types it was concluded that most of the staphylococcal infections were sporadic and not due to epidemic outbreaks

GENERAL AND LOCAL TREATMENT WITH CLOXACILLIN

Sven Åke Hedström (Lund Sweden)

Chronic osteomyelitis due to *Staphylococcus aureus* was treated by high doses of antibiotics (cloxacillin 1 g 6 times daily) by mouth Fistulae were treated locally by antibiotics in a dextran vehicle. The prognosis and treatment period (minimum of 6 months with oral treatment) were discussed and the results reported

To be published in *Acta orthopaedica scandinavica.*

FUCIDIN TREATMENT OF CHRONIC STAPHYLOCOCCAL OSTEITIS AND OSTEOMYELITIS

Jørgen Ernst (Juelsminde Denmark)

The results of Fucidin treatment of subacute and chronic staphylococcal osteitis and osteomyelitis are reviewed The material is subdivided into two main groups 32 cases in 31 patients exclusively treated with Fucidin in dosages of 750 mg four times daily and 41 cases in which Fucidin was employed in combination with other antibiotics chiefly methicillin and novobiocin The group includes eight patients from the pure Fucidin group and 33 new patients In eight of these two courses of treatment were employed at such long intervals that these are regarded as separate instances In the combination group Fucidin was employed in dosages of 1500 mg daily In each of the main groups the patient material was subdivided into closed cases treated conservatively chronic fistulous cases treated conservatively and cases submitted to operative treatment The results show that the closed conservatively treated cases behave otherwise than the open cases since among 13 closed conservatively treated cases the results were good in 92 per cent The remaining 60 cases were open In the pure Fucidin group results were good in 37.5 per cent whereas in the group with combined treatment 63.9 per cent showed good results The difference, however is not highly significant. Of the 60 open cases 20 were conservatively and 40 operatively treated Among the operatively treated cases 6 per cent had good results as contrasted with 30 per cent in the conservatively treated cases The difference is 2.23 bigger than the mean error—which is significant

Few complications were encountered but it is emphasized that in four of the patients raised values for liver function tests were found These were transient in three patients but in the fourth resulted in a prolonged illness with ascites like increase of the abdominal circumference

TREATMENT OF CHRONIC OSTEITIS WITH FUCIDIN AND PRO STAPHLIN

Hans Bohr & E Larsen (Copenhagen Denmark)

The investigation includes 5 patients who have suffered from chronic fistulating osteitis for more than 2 years and who have undergone several operations on the bone with removal of sequestrae Cultures from the wound before treatment in all cases grew *Staphylococcus aureus* which was resistant to penicillin but sensitive to Fucidin (Leo) and Pro Staphlin (Lundbeck) Fucidin and Pro Staphlin were given daily in 4 doses of 1.5 and 2 g respectively as out patient treatment This was carried out for more than 3 months with cultures from the wound every

fortnight and control of the haemoglobin percentage leukocytes, sedimentation rate, serum creatinine serum electrophoresis serum transaminasis and G.O T The staphylococci disappeared little by little from the wounds during the treatment but already 2 weeks after cessation of treatment staphylococci were again demonstrated in 3 of the cases showing the same resistance pattern and phage types as before treatment. There were no signs of toxic effects from the medication administered but periodical dyspepsia and diarrhoea occurred despite Paragurth tablets given simultaneously Though the material is small it seems to prove that even through prolonged treatment with these antibiotics complete asepsis of chronically infected bone foci cannot be obtained

NON SPECIFIC SPONDYLITIS

S Ahlback S Collert & L Lindberg (Stockholm and Malmo Sweden)

Sixty four cases of haematogenous spondylitis 21 women and 43 men treated 1950–1966 at the Departments of Orthopaedic Surgery St Goran s Hospital Stockholm and Malmo General Hospital have been investigated

Seven were localized to the cervical region 57 to the thoracal lumbar region The onset was simultaneous with an urinary infection in 16 ca es with a respiratory infection in 4 cases and with a skin infection in 3 cases

As half of the cases were sent to hospital as tuberculous spondylitis we have tried to find differences between tuberculous and septic spondylitis in their early courses

	Septic	Tbc
Onset	Acute or subacute	Chronic
Early fever	Common	Uncommon
Sed rate	Often very high	Moderately high
ASTa	Often high	Often normal
Destruction	Over the whole endplate	One single cavity
Sequestrae	Occasional	Abundant
Gibbus	Uncommon	Common

The diagnosis was confirmed by operation in 16 cases and by needle biopsy in 12.

In the lesion *Staphylococcus aureus* was found in 13 cases *S albus* in 2 *B coli* in 2 *B proteus* in 2

Antibiotics were given for more than 3 months.

The effect of this treatment is difficult to judge as the septic spondylitis seems to have a strong tendency to spontaneous healing in 10–12 months

38 patients were followed up after 2 years 35 were found to have no back pain at all In about half of the cases a spontaneous fusion was found on roentgenograms All 38 cases were judged as roentgenologically healed

THE DISTRIBUTION OF DIHYDROSTREPTOMYCIN AND TETRACYCLINE IN STAPHYCOCCAL ARTHRITIS AN EXPERIMENTAL AND AUTORADIO GRAPHIC STUDY

Lars Lindberg & Bo Lundberg (Malmo Sweden)

The distribution of these two antibiotics in standardized experimental staphylo coccal arthritis in golden hamsters and rabbits was studied with an autoradiographic technique which makes it possible to identify tritium labelled water soluble substances on a *cellular level in different tissues*

Intramuscularly given tetracyclin was found to be highly concentrated in bone tissue whereas the concentration in soft tissues inclusive of pus and other kinds of infectious tissues was comparatively low No difference in concentration was found between the different soft tissues, the tetracyclin was evenly distributed among them all Intramuscularly given dihydrostreptomycin was found to be highly concentrated in pus and in cartilage Already 15 minutes after the injection the concentration in the abscesses was very high compared with the surrounding tissues and blood.

After intra articular injection both antibiotics were found to be strictly located to the cavity and abscesses with open communication with the joint. No diffusion was found to closed recesses

The conclusion of the results is that very high concentration of antibiotics can be attained by local injections of antibiotics in an infected joint, but that intra muscular injections must be given if all parts of the lesion shall be reached.

OPERATIVE TREATMENT OF OSTEOMYELITIS WITH PRIMARY WOUND CLOSURE

Knud Jansen (Copenhagen Denmark)

Adequate blood supply is generally agreed to be essential in fracture healing and in fighting bone infections. Still we experience examples of neglect of this principle by destruction of both the endosteal and periosteal vessels by medullary *nailing and secondary plating—and in infectious cases by packing the periosseous* space with gauze while waiting a secondary healing of the bone and soft tissues

Since 1951 I have applied the principle of primary closure to cases of pyogenic hematogenous or traumatic osteomyelitis

The skin is incised and pre-existing retracted scars or fistulas excised. After probe drilling the medullary cavity is opened. The periosteum, when present, is preserved The bone cavity is reamed carefully pus and visible necrotic bone being removed. The cavity is then filled with cancellous bank bone mixed with penicillin and some additional antibiotic Periosteum muscle fascia and skin are sutured and adequate general antibiotic treatment is commenced with adjustment accord ing to the growth analysis of the bacterial probes

In cases with sufficient soft tissue cover recovery has been achieved within two weeks In cases of skin defects in particular in tibial and ankle regions, a preliminary skin graft (cross leg flap) may be necessary In cases of instability (pseudarthrosis arthrodesis) immobilization is an essential additional measure.

The results have been satisfactory and in concordance with the patho-physio logical principle applied



Figure 1a Before surgery Figure 1b After surgery Figure 1c Four years later

Figure 1 Acute in chronic osteomyelitis distal end of femur (34 year old male) Healing within two weeks No symptoms since

STUDIES ON DICLOXACILLIN (DICLOCIL®)

P Holstein & O Hvid Hansen (Hillerod Denmark)

Dicloxacillin is a semi synthetic penicillin (isoxazolyl penicillin) active against penicillinase producing staphylococci It is stable in acid and affords approximately the same serum level upon intramuscular and oral administration The degree of absorption is independent of stomach contents It is strongly bound to serum protein

At the Frederiksborg Country Central Hospital Hillerod Denmark this agent has been used for long term oral treatment of osteitis In this connection we investigated whether the substance was excreted in the wound discharge after oral dose of 1 g In one clean granulating wound two sluggish granulating wounds, one necrotic wound without granulation tissue and in one chronic osteomyelitis fistula a definite increase in the antibiotic concentration was found in the discharge about 6 hours after administration—and thus a definite antibiotic effect.

PRELIMINARY EXPERIENCE OF DICLOXACILLIN IN THE TREATMENT OF OSTEITIS

O Hvid Hansen & P Holstein (Hillerod Denmark)

Dicloxacillin was used as the only antibiotic on 9 patients 5 of whom had chronic osteitis previously treated with a large number of other antibiotics without any effect and 4 had fresh osteitis Adequate surgical treatment was given *Staphylococcus aureus* was isolated from 6 patients and *Staphylococcus albus* from 4

Healing was obtained in 7 patients whereas in 2 the effect was questionable Gastroenteritis recurred in one patient We shall continue using this agent

(*One year after the treatment one patient has had a recurrence* Another patient, in whom the effect had been questionable is cured)

DISCITIS CLOSED SPACE INFECTION AFTER LUMBAR DISCUS PROLAPS OPERATION

Soren Pilgaard (Arhus Denmark)

The word discitis is used alternately with the term closed space infection The symptoms of discitis are initially severe spasmatic pain in the back and the posterior part of the legs shortly after operation for protruded lumbar disc There can be atypical abdominal pain (Sullivan) The disease can be without a rise in temperature (Lowmann) There is always a strongly elevated sedimentation rate and changes on the X ray pictures

At the Orthopedic Hospital in Arhus 502 patients with lumbar discus prolaps have been operated on in the period from 1962–67 Of these patients 15 developed discitis The first 24 hours after operation the condition was normal

1 In the period 2 ?8 days postoperatively all patients complained of severe back pain

2 3 patients had normal temperature the rest had fever 2-30 days after the operation

3 The most pronounced symptoms was the highly elevated SR (30–121 mm/h)

4 In all 15 patients the end result on the X ray pictures was a total bone block between the two vertebrae on either side of the affected discus

Only one patient had meningeal reaction

The treatment was bedrest leg traction and sedatives Nine patients received anti biotic treatment

End result 10 patients back at work 3–11 months after the operation 2 received invalid pensions 3 patients were not working after 12 months

Conclusion Discitis after prolaps operation is an occasional complication which can be alarming and always prolongs the postoperative phase After our experience we can promise the patient with discitis a good and painless lower back

SYNDACTYLIZATION IN THE MANAGEMENT OF CERTAIN TOE DEFORMITIES

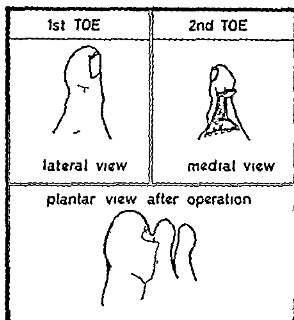
Erin Madsen (Soro Denmark)

Syndactylization was used for the treatment of overlying toes and of lax toes following resection for hallux valgus

On the longer toe a flap of skin is freed on the dorsal as well as plantar aspect and laid on the shorter toe he e the edges of the flaps are outlined The skin between the marks is removed except for the distal 1 cm which instead is fashioned as a flap with distal attachment This flap is applied to the longer toe Thus inverted skin edges are avoided The toes are united by 2 or 3 thin catgut sutures in the soft tissues taking care that the position of the shorter toe is adequate so that its nail does not hurt the other toe The skin flaps are trimmed and sutured The toes are held together by gauze no other dressing

In the presence of contracture tenotomy on the extensor tendons has been performed a few times and in fixed hammer toe Slomann s operation has been used twice

Out of 15 patients 13 were seen 1–17 years after the operation—a total of 21 operated toe In all cases the result was excellent from the subjective as well as objective point of vie



A CLINICAL AND RADIOLOGICAL 20 YEAR FOLLOW UP STUDY OF TRANSIENT SYNOVITIS OF THE HIP

Alf L Nachemson & Sten Scheller (Gothenburg Sweden)

To be published in Acta Orthopaedica Scandinavica

OPERATIVE TREATMENT TO IMPROVE THE FUNCTION OF THE EXTREMITIES OF HEMIPLEGICS ESPECIALLY REGARDING GAIT FUNCTION

J Kunov (Copenhagen Denmark)

A 5 year material comprising 47 hemiplegic patients is reported 34 female and 13 male patients mostly under 60 years of age (23 right sided 24 left sided)

The hemiplegia had most often been stationary throughout several years.

Prominent feature was gait disturbance because of area 6 paresis type with spastic drop foot and varus deformity

Along with training and redressment splinting and operative treatment were used alternatively or in combination

The operations used were for stabilizing as well as counter acting spasms and contractures Types of operations used transpositio tend. tib post + allongatio tend. calc in 9 op a m Silverskiold in 6 transcisio tend tib post in 6 subtalo arthrodesis in 3 cases and in 20 cases various combined operations most frequently transcisions and transpositions of tendons of tibialis posterior and anterior

37 patients had a satisfactory result of the operation 27 patients got an undoubtedly improved gait function and 10 could do with a lesser bandage. 25 patients have been followed up for more than 1 year 16 for more than 2 and 6 for more than 5 years

Operative treatment contributes essentially to improving the function of the extremities of these patients as well as other patients with diseases of the CNS.

BLOUNT'S DISEASE

Mohammed Zager (Apelvikstrand Sweden)

The author collected 124 cases suspected of having Blount's disease from 15 Swedish hospitals and presented 40 confirmed cases operated upon by Blount epiphyseodesis (14 cases) or osteotomy (24 cases) Two patients had both procedures. Of the patients, 23 were girls and 17 boys, 25 of the cases are considered infantile and 15 adolescent according to the classification of Langenskiöld and Blount.

From this material it seems permissible to conclude that Blount epiphyseodesis is suited for the younger group (2–13 years) and osteotomy for the older (over 14 years of age) The author suggested that it might be the characteristics of the disease which determine its course irrespective of the surgical treatment but hoped to be able to answer this question in the future

SURGICAL TREATMENT OF KNEE JOINT INSTABILITY DUE TO BLOUNT'S DISEASE

H Storen (Oslo Norway)

To be published in Acta Orthopaedica Scandinavica

WHY SYNOVECTOMY IN RHEUMATOID ARTHRITIS?

Erik Moberg (Gothenburg Sweden)

Figure 1 shows the conception of the problems to which I have come after about 12 years experience of synovectomy The number of operations has increased rapidly In 1967 300 synovectomy operations were performed many of them including several hand joints The present discussion concerns the first third of the Figure the period in which so called preventive surgery is recommended

From the swollen synovial tissue special leukocytes will go out into the joint fluid and give rise to lysosomes, active against the cartilage One must remember that the bone and synovial tissue are linked together by a special vascular system completely separate from the vessels to the fibres capsules and the aponeuroses It is now known that the synovial granulations appear at typical locations in the joint The destruction to the bone also has typical locations to the region of the so-called nutrient foramina A marked irregularity however characterizes the lesions to the cartilage The picture is similar to the one in corrosion of a metal surface Where destruction starts it will dig deep in some cases in others there will be small superficial lesions over a large surface. In the joints all facts known indicate that a factor in the joint fluid is active here presumably an enzyme

The aim of synovectomy will therefore be to reduce the bone destruction by cutting the vascular connections between bone and synovial tissue and to stop or reduce the flow of destructive fluids into the joint. If a level low enough to be counteracted by the repairing forces in the cartilage can be obtained, the disease will stop locally I have examples in which this has been possible for as long as

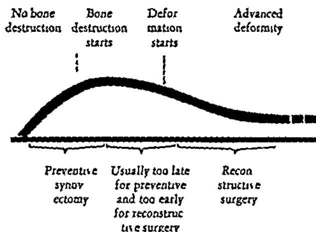


Figure 1 Local development in joints

11 years after surgery although the disease has advanced in other joints in the same hand In a re explored symptom free joint 10 years after synovectomy the synovial tissue macroscopically was normal but microscopically showed only a thin fibrous lining and no real synovial tissue

Mobility will in early cases usually remain intact after synovectomy The pain will disappear Of course recurrences are not infrequent but as a whole very much is gained with the synovectomy and for a considerable period of time Table 1 shows some of the results obtained

Table 1 Results of synovectomy (most cases from the hand) (our indications)

Follow up time (yrs)	No recurrence	Recur rences
10–11	Some observations	
5	70 % free from pain some with recurrence	30 %
3–10	40 %	

RESULTS OF EARLY WEIGHT BEARING IN CASES OF OPERATED SUBCAPITAL FEMORAL NECK FRACTURES

Sven Owe Hoggquist (Malmo Sweden)

A material of 388 patients with medial hip neck fractures was nailed according to Sven Johansson Every second patient was allowed to carry full weight after 2 weeks and the other half of the group after 6 weeks

The largest group was between 71 and 85 years 48 per cent (Table 1) The post operative mortality within 6 weeks was in both groups 4 per cent Wound healing was normal in 93 per cent of the women and in 96 per cent of the men Totally there were 4 per cent wound infections and 5 per cent haematomas

Table 1 Age groups Weight bearing after operation

Age	2 weeks ♀	6 weeks ♀	2 weeks ♂	6 weeks ♂	%
<70	69	61	10	16	40
71 85	/8	85	12	11	48
>85	?8	12	4	2	12

Significant sliding of nails within 1 year occurred in the two groups in about the same frequency (30 per cent) The greatest occurrence was within the fir t 6 weeks (Table 2)

Table 2 Sliding of nail

	2 week group (163 pat followed up)		6 week group (149 pat. followed up)	
	No of cases	%	No of cases	%
< 6 weeks	21	13	22	15
(weeks-6 months	19	12	16	11
6 months-1 year	6	4	6	4

Excellent primary result within the first year was defined as no pain no hindrance in movement, and no limp

	2 week (%)	6 week (%)
Excellent results	23 4	18 8
Some persistant discomfort	36	45 1
Not possible to evaluate due to other illness	15 5	11 3
Dead within the first year	8 8	7 5
Not available for examination	16 6	15

The most favourable group is thus that with early weight bearing

Caput necroses can not be evaluated until more than 2 years have passed and not all patients have been followed up this long The comparison between the two groups does not reveal any difference Men have so far shown an occurrence of caput necrosis t ice as great as women

We have thus found that primary results within 1 year postoperatively are n t worsened f the patient is mobilized and allowed full weight bearing already after 2 weeks r ther than after 6 weeks

2

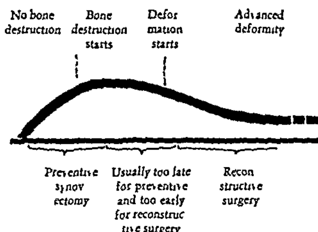


Figure 1 Local development in joints

11 years after surgery although the disease has advanced in other joints in the same hand In a re explored symptom free joint 10 years after synovectomy the synovial tissue macroscopically was normal but microscopically showed only a thin fibrous lining and no real synovial tissue

Mobility will in early cases usually remain intact after synovectomy The pain will disappear Of course recurrences are not infrequent but as a whole very much is gained with the synovectomy and for a considerable period of time Table 1 shows some of the results obtained

Table 1 Results of synovectomy (most cases from the hand) (our indications)

Follow up time (yrs)	No recurrence	Recur rences
10–11	Some observations	
5	70 % free from pain some with recurrence	30 %
3 10	40 %	

RESULTS OF EARLY WEIGHT BEARING IN CASES OF OPERATED SUBCAPITAL FEMORAL NECK FRACTURES

Sven Owe Hagquist (Malmo Sweden)

A material of 388 patients with medial hip neck fractures was nailed according to Sven Johansson Every second patient was allowed to carry full weight after 2 weeks and the other half of the group after 6 weeks

The largest group was between 71 and 85 years 48 per cent (Table 1) The post operative mortality within 6 weeks was in both groups 4 per cent Wound healing was normal in 93 per cent of the women and in 96 per cent of the men Totally there were 4 per cent wound infections and 3 per cent haematomas

INDEX

PROCEEDINGS OF THE NORDISK ORTOPÆDISK FORENING'S 34th ASSEMBLY

Acta orthop Scandinav 40 689–695 1970

Institute of Experimental Research in Surgery University of Copenhagen (Head H H Wandall M D) and the Orthopaedic Hospital Department I (Head Professor A Bertelsen M D) Copenhagen

DEFECT PSEUDARTHROSES

An Experimental Study on Rabbits

K Baadsgaard

Received 20 iv 69

One of the difficulties in assessing the results of experimental bone grafting is posed by the inability to decide with certainty whence the new formed bone has developed

It may have issued from the recipient site and have invaded the graft by creeping substitution It may have issued from surviving cells in the graft Lastly it may have arisen from the surrounding soft tissues by metaplasia induced by the graft

Most often grafting to fresh bone defects has been used In long bones these have usually been small defects as a circumferential total defect cannot be obtained without loss of stability As a result these studies have been disturbed by the response of the recipient site to the fresh bone injury a pronounced regeneration of bone which often completely overshadows the weaker reaction of the graft

In grafting to cancellous bone as in the spongiosa test described by Maatz et al (1954) such pronounced callus formation also takes place in the recipient site that one gets an impression rather of the acceptability of the graft than of its independent osteogenetic effect

Ectopic bone grafting is well suited for elucidating certain biological and immunological properties of bone tissue It is less suited for direct evaluation of the clinical value of a bone graft as it is not possible to observe the reaction of an indolent bony recipient site to the graft

Therefore an attempt was made to induce in the long bones of rabbits a defect which was stable and which did not heal spontaneously in order thereby to obtain a recipient site for use in comparative studies of various types of bone grafts

Aided by a grant from the Danish Science Foundation

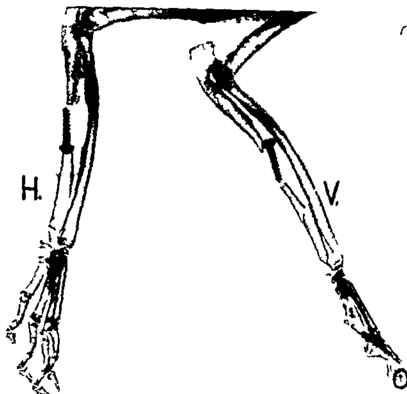


Figure 1 6 weeks after the first operation The polyethylene caps are fixed to each other by a screw There is only sparse regeneration of bone at the edge of the polyethylene caps

MATERIAL AND METHODS

The experimental animals were 30 adult or almost adult rabbits of mixed race, ranging in age from 6 to 12 months

The rabbits were anaesthetized with Nembutal approx 40 mg/kg body weight. The operative sites were shaved and disinfected with iodine As a prophylactic measure penicillin was administered locally and intramuscularly a total of 300 000 units

1 13 rabbits had operations on both hindlegs A defect 1 cm large was sawn out somewhat above the middle of the femur The bone ends were covered with poly ethylene caps, and osteosynthesis was performed providing a strong metal splint, Kuntscher nail, or a strong intramedullary vitallium screw

2 17 rabbits had operations on both forelegs The ulna was exposed, leaving the periosteum intact on the bone A total defect 0 75 cm, was sawn 3 5 cm distally to the tip of the olecranon process. The calcified interosseous membrane was broken so that both ulnar fragments were free of the radius The cavity and the adjacent muscle surfaces were painted with trichloroacetic acid. The free bone ends of the ulna were covered with a polyethylene cap whose bottom was half the thickness

of the defect and which had 7 mm sides so that the caps were firmly fixed in relation to each other Furthermore, the caps were fixed to each other by a screw (Figure 1)

6–10 weeks later the rabbits had re operation removing the screw and polyethylene caps by a technique as atraumatic as possible. The resulting cavity and the bone ends were shielded from the radius by a 1 mm polyethylene membrane measuring 3 × 20 mm

Every 2 weeks one rabbit was killed the last one 6 months after the latter operation The forelegs were X rayed, the specimens dissected and by the conventional histological technique haematoxylin-eosin stained preparations were made cut longitudinally Three sections of each preparation from different levels were studied.

RESULTS

1 *Bone defects in the femur* As stated above it was endeavoured to maintain a defect in the femur by means of polyethylene caps and different osteosynthetic material Out of the 13 rabbits thus operated 9 had to be considered technical failures During the osteosynthesis fracture occurred or else the osteosynthesis material failed later resulting in secondary displacement In the remaining 4 cases the rabbits failed to thrive and had to be killed before the planned removal of the osteosynthesis material It could be ascertained that healing may be prevented by covering the bone ends with polyethylene caps Histological examination revealed necrosis of the bony tissue and bone marrow in the part which had been covered by the polyethylene

2 Bone defects in the ulna This operation was well tolerated When a stable result was obtained the rabbits used their forelegs normally immediately after the operation All gained weight In one case infection appeared on one side

X ray examination showed that in the course of the observation period the radius underwent increasing hyperthrophy Synostosis occurred between the uncovered parts of the ulna and the radius proximally and distally If the osteosynthesis material failed at an early stage of the course stress fracture of the neck of the radius and displacement occurred This was observed in 3 cases But when the polyethylene caps and osteosynthesis material were removed later than the sixth week the operated site was completely stable When subperiosteal resection of the bone was avoided regeneration of bone beyond the edge of the polyethylene caps was slight (Figure 1) During the further course there was after the removal of the osteosynthesis material only sparse regeneration of bone mainly around the proxi

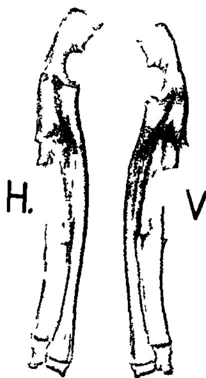


Figure 2 8 weeks after removal of the osteosynthesis material Hypertrophy of the radius The defect has not healed

mal fragment (Figure 2) Healing of the defect did not occur in any case

Histological examination showed from the second week incipient vascularization osteoclastic resorption and creeping substitution of the corticalis in the bone ends This increased during the experimental period but even the 6 month old preparations showed distinctly necrotic remnants of bone At an early stage periosteal and endosteal callus appeared spreading towards the defect which it seldom entered (Figure 3) The medullary cavity filled with normal bone marrow and closed with callus against the defect In the second week the defect contained remnants of haematoma and granulation tissue Gradually this tissue assumed the nature of denser connective tissue and from the sixth week it was sprinkled with minor areas of fibrocartilage premyeloid and myeloid tissue (Figure 4) At times the oldest preparations would show a small islet of bony tissue but osseous healing did not occur in any case The defect was always surrounded by a dense connective tissue membrane



Figure 3 6th week Necrotic bone end in the process of creeping substitution Fibrous tissue in the defect

DISCUSSION

Only a few experimental studies on pseudarthroses on animals have been reported previously Martin (1920) Lexer (1922) and Wallich (1924) induced pseudarthroses on dogs by segmental resection of the ulna or radius maintaining the periosteum or marrow and studied the aetiology of pseudarthrosis

According to Key (1934) a total defect in the ulna of dogs does not heal if the defect measures more than 1½ times the diameter of the bone He used such fresh defects as recipient sites in his transplantation experiments However in 2 out of 6 control experiments the empty defect healed spontaneously Heiple et al (1967) induced defects in the dog ulna twice the diameter of the bone and found that 1 out of 7 empty defects healed spontaneously At 3 months only 4 out of 11 fresh autologous grafts showed bony union to both fragments From



Figure 3. 10th week. Fibrous and myeloid tissue in the defect.

these findings it seems evident that fresh defects in the dog ulna have a certain tendency to spontaneous healing and that the operative site is so unstable that even autografts often fail to take.

The method used in the present study gives a stable operative site which does not heal spontaneously in 6 months. The defect is surrounded by a fibrous membrane and contains fibrous tissue, fibrocartilage and small amounts of osteoid tissue. Proximally and distally it is delimited by necrotic and new formed bone. Pathologically, the condition is similar to pseudarthrosis and appears to be well suited as the recipient site for bone grafting.

SUMMARY AND CONCLUSION

A method for inducing a pseudarthrosis like defect in the rabbit ulna is described

It is concluded that such a defect is well suited as a recipient site for bone grafts in studies of their osteogenetic effect

REFERENCES

Heiple K Kendrick R E Herndon C H & Chase S W (1967) A critical evaluation of processed calf bone *J Bone Jt Surg* 49 A 1119–1127

Key J A (1934) The effect of a local calcium depot on osteogenesis and healing of fractures *J Bone Jt Surg* 16 176–184

Maatz R Lentz W & Graf R (1954) Spongiosa test of bone grafts for transplantation *J Bone Jt Surg* 36 A 721–731

Martin B (1920) Über experimentelle Pseudarthrosenbildung und die Bedeutung von Periost und Mark *Arch Klin Chir* 114 665–722.

Lexer E (1922) Über die Entstehung von Pseudarthrosen nach Fracturen und Knochentransplantationen *Arch Klin Chir* 119 520–607

Willich C T (1924) Experimentelles über Knochenregeneration und Pseudarthrosenbildung *Arch Klin Chir* 129 203–231

Acta orthop Scandinav 40 696–707 1970

Institute of Experimental Research in Surgery (Head H H Wandall MD)
University of Copenhagen and the Orthopaedic Hospital Department I
(Head Professor A Bertelsen MD) Copenhagen

KIEL BONE
IN THE TREATMENT OF PSEUDARTHROSIS

An Experimental Study

K Baadsgaard

Received 20 ii 68

In 1934 Orell published a comprehensive study on the applicability of macerated bone in surgery He used bovine bone which he cleaned mechanically and treated with saline solutions hot potassium hydroxide and acetone This material he called os purum When he implanted os purum subperiosteally it became invaded by callus and was converted into an os novum He obtained good results by using os purum in the treatment of tuberculosis of the bones cysts and arthrodeses For pseudarthroses however he preferred using os novum

For some years this method gained ground but thereafter it was practically abandoned although Goff (1944) submitted a fairly large clinical material successfully treated by os purum

Incidentally interest appeared to centre more on bone bank problems until Bauermeister (1958) on the basis of a comprehensive experimental study laid down the principles for preparing the Kiel bone graft viz processing of young calf bone with H_2O_2 and extraction of the lipids by acetone

He found this material to be equal to autologous bone and this seems to have been confirmed by a number of experimental and clinical studies (Maatz & Bauermeister 1957 Koch 1957 Bauermeister 1961 Schilling & Nockemann 1962 Fuchs et al 1963 Hallen 1966)

American workers too have displayed an interest in processed heterologous bone In their experimental studies Bassett & Creighton (1962) and Karges et al (1963) arrived at the same result as Bauer

Aided by a grant from the Danish Science Foundation

meister and favourable results were obtained by Hurley et al (1960) and Anderson et al (1963) in large clinical materials

However negative reports have appeared also In a large material of pseudarthroses Hopf (1957) found 44 per cent poor results with Kiel bone and on the basis of an experimental study using Squibb Surgibone Heiple et al (1967) developed a highly negative attitude

At the SICOT meeting in Paris 1966 Maatz (1967) recommended Kiel bone for the treatment of non union and delayed union finding 96 per cent good results while Witt (1967) advised against using Kiel bone

Accordingly there is still disagreement concerning the indication for using processed heterologous bone

MATERIAL AND METHOD

The experimental animals were 24 rabbits of mixed race weighing between 2.5 and 4 kg and ranging in age from 6 to 12 months By a previously described technique (Baadsgaard 1969) defect pseudarthroses were produced on the ulna The defect measured 3/4 cm and was situated 3.5 cm distally to the tip of the olecranon process

6–10 weeks later the rabbits were subjected to re operation the osteosynthesis material was removed, and grafting was done on the right with Kiel bone and on the left with autologous cancellous bone In two cases a Kiel bone graft was used for both sides In 6 instances cortico cancellous Kiel bone was used and in the others cancellous The autologous graft was sawn out of the iliac bone immediately before the transplantation The grafts which measured about 3 × 4 × 25 mm were placed as on lay grafts on that side of the pseudarthrosis which faced away from the radius (Figure 1) and were fixed to the bone ends with silk. Proximally as well as distally they reached to healthy bone A polyethylene plate was placed between the radius and ulna so that ingrowth of callus from the radius into the pseudarthrosis was prevented In 3 cases infection occurred around the autologous graft These specimens are not included in the material which thus comprises 26 Kiel bone grafts and 19 autologous controls

The rabbits were killed at the time intervals stated in Table 1 Two days before they were killed 45Ca 200 microcuries and tetracycline, 100 mg were injected intramuscularly The specimen was assessed macroscopically by dissection and X rays Thereafter it was divided transversely and the proximal half of the graft with the proximal recipient site was used following decalcification and embedding in paraffin for conventional histological examination The specimen was cut longitudinally so that both the graft and recipient site were included, and stained with haematoxylin eosin Three sections from different depths were studied. The remaining part of the specimen was used for undecalcified ground sections, embedded in methyl metacrylate and sawn transversely A cross section of the graft in a level with the middle of the defect as well as a cross section from a more distal site containing graft as well as distal recipient site were studied The sec

Table 1 Results

Age of graft (weeks)	Union proximally		Union distally		Callus in the graft on a level with the defect		Measurement of ^{45}Ca c/min	
	K	A	K	A	K	A	K	A
2	—	+	—	—	—	+	20	116
3	+	+	+	+	—	+	17	402
4	—	+	—	+	—	+	9	316
4	—	—	—	—	—	+		
5	+	+	+	+	—	+	37	261
6	+	+	+	+	—	+	37	551
6	+		+		—			
7	+	+	+	+	+	+	217	509
8	+	+	—	—	—	+	90	430
8	—	—	—	+	—	+		
10	+	+	—	+	—	+	100	462
10	+		—		—		11	
	—		—		—		7	
11	+	+	—	+	+	+	48	98
11	—	—	—	—	—	+		
12	—		—		—		[illegible]9	
	+		—		+		1[illegible]8	
12	—		—		—			
12	+	+	—	+	—	+	24	111
14	+	+	+	+	+	+	10[illegible]	214
15	+	+	+	+	+	+	[illegible]9	1[illegible]3
15	+	+	—	+	—	+	40	105
15	+	+	+	+	—	+		
17	+	+	—	—	—	+		
17	-		—		—			
40		+	—	+	—	+		
Total	16/26	16/19	8/26	14/19	5/26	19/19		
(%	62	84	31	74	19	100)		

Symbols K = Kiel bone graft A = Autologous graft.

tions were manually ground to a size of 100 μ and studied autoradiographically by the contact method microradiographically and by fluorescence microscopy The activity in the sections was measured directly by a Geiger Müller tube Positives were made of the microradiographs all of which were equally enlarged and the area was measured by planimetry The result of the activity measurements was corrected for background radiation and for any difference in the area of cross section between the Kiel bone and the autologous graft

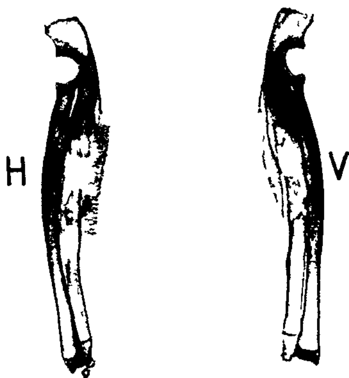


Figure 1 [illegible]th week Kiel bone graft marked H autologous graft V

RESULTS

The necrotic bone ends which delimit the defect in the ulna become revascularized and are gradually replaced by creeping substitution

The Kiel bone graft is rapidly vascularized from the surrounding soft tissues Two weeks after the transplantation it has been invaded by granulation tissue and only small remnants of haematoma are left (Figure 2) Gradually the connective tissue assumes a firmer nature At a late stage of the course bone marrow may occur in the Kiel bone but this marrow is of the active type only in the event of simultaneous regeneration of bone

The Kiel bone graft gets bound to the recipient site by loose connective tissue From the ulna osteoid tissue and callus grow towards the graft reaching it by the third week and invading its profound part new bone forming directly on the dead trabeculae (Figure 3) Gradually the bone formation may spread further inwards in the

Figure 2 2nd week Central part of the Kiel bone graft invaded by amply vascularized connective tissue



graft but it seldom reaches its superficial part ... llus ... seldom traverses the Kiel bone graft on a level wi... ect (Fi... gures 4–5)

Throughout the course numerous osteoclasts are ... clear... ly an increasing resorption is taking place (Figure ... the 40 week specimen the Kiel bone graft has been com... rbed (Figure 7) The histological preparations did not sh... im... munological reaction

The results for the 6 cortico cancellous grafts do n... those for the cancellous Kiel bone grafts

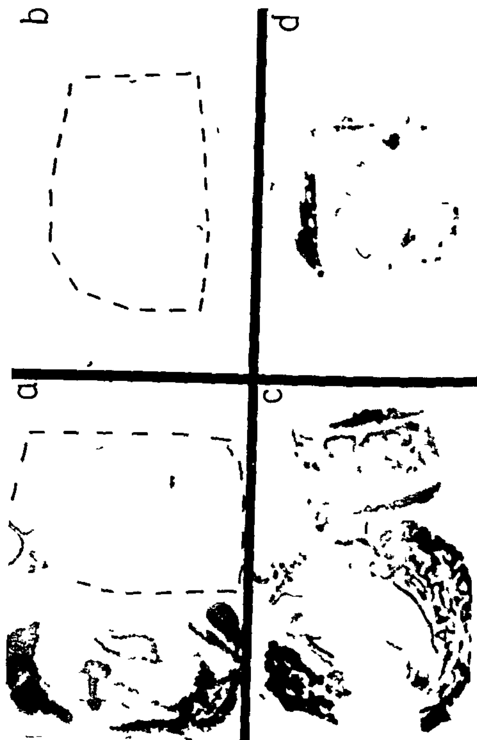
By comparison the autologous grafts showed a m... more reliable union In all cases there was new formati... the graft on a level wi... t fect and substitution



Figure 3 3rd week Ingrowth of callus into the Kiel bone graft from the proximal recipient site



Figure 4 th week From the Kiel b ne graft on a level with the lefect The lacunae are empty Some apposition of new formed bone and osteo lastosis


b
d
a
c

actory agreement between the values found and the amount of new ormed bone in the same rabbit The results are listed in Table 1 Indi idual variations are seen in the counts presumably as a sign of a lifference in age calcium balance and dosage Only two cases from he eighth to the tenth week showed strikingly high values for the kiel bone graft without showing regeneration of bone in the specimen However the corresponding values for the autologous graft were 4–5 imes higher A rabbit provided with a kiel graft on both sides 12 veeks previously showed new bone formation in one graft but not in he other The count for diffuse labelling in the necrotic graft was 29 n that which also contained new formed bone 128

DISCUSSION

On autoradiography of normal bone the uptake of ⁴ Ca was found to be partly faint and diffuse and partly more intense viz in not fully calcified Haversian systems the so called hot spots

Cohen & Maletskos (1963) have performed quantitative determinations of the specific activity of the diffuse uptake of hot spots and of callus by measurements on autoradiographs and by direct measurement of samples of homologous grafts callus and recipient site They found the diffuse uptake to be low and constant proportional to the administered dose and independent of the time of administration as well as of the nature of the surgical procedure For comparison the specific activity of the hot spots was higher on an average by a factor 20 By measurement of samples of the graft from animals injected two weeks after the transplantation they found the specific activity to be higher than the diffuse uptake by a factor 56–57 and in the callus by a factor 55–86

In the present experiments all the grafts had become fully vascularized at the time of the injection The autoradiographs showed a faint diffuse uptake apparently equal in the kiel bone and in the necrotic parts of the autologous graft All preparations showing new bone formation showed several times higher counts The share of passive diffuse uptake by the necrotic bone in this process could only have been modest and approximately the same is true for the kiel bone graft and for the autologous graft

The experimental conditions were not strictly standardized in respect to dosage period from injection until sacrifice the rabbits calcium balance and age Moreover for practical reasons the results are

not given as specific activity but are related to the volume of the sample. Within the same rabbit however I obtained a quantitative expression of the biological activity of the studied grafts.

The experimental results differ from several of those mentioned in the introduction. One explanation is no doubt a difference in the experimental method. Maatz & Bauermeister, Fuchs et al. and Hallen used the Maatz spongiosa test, whereas Bassel & Creighton and Karges et al. transplanted to small defects in cortical bone. The applicability of such experimental models in studying the clinical value of bone grafts has previously been discussed (Baadsgaard 1969). More agreement was found with the results of Heiple et al. who employed large total defects in long bones as recipient sites.

In comparing experimental results it must be realized that processed heterologous bone prepared by different methods may be of different composition. Gattow & Munzenberg (1963) for instance found the Kiel bone to have an unchanged collagen content and an unchanged crystal arrangement, whereas Quigley & Hjorting-Hansen (1962) in ethylene diamine prepared bone found a nitrogen content of 0.4 per cent and an unchanged crystal arrangement. Fuchs et al. found in the Kiel bone a nitrogen content of 1.9 per cent, viz. close to normal for dried defatted bone. They felt that they could demonstrate that the greater the protein content the greater was the osteogenetic effect of processed heterologous bone.

SUMMARY AND CONCLUSION

On defect pseudarthroses produced on rabbits comparative studies of Kiel bone and fresh autologous cancellous bone applied as onlay grafts were done. The specimens were studied radiologically, histologically and by fluorescence microscopy and quantitative determination of new bone formation was performed using ^{45}Ca.

Union of the Kiel bone graft to the recipient site proximally as well as distally in the pseudarthrosis was slower and more uncommon than in the autologous control experiments. On a level with the defect new bone formation was found in 19 per cent of the Kiel bone grafts as compared with 100 per cent of the autologous grafts from the iliac crest.

On this basis it is concluded that the Kiel bone graft is less suited than fresh autologous bone grafts in the treatment of defect pseudarthroses.

REFERENCES

Anderson K J, LeCocq J F & Mooney J G (1963) Clinical evaluation of processed heterogenous bone transplants *Clin Orthop* 29 248–263

Baadsgaard, K (1969) Defect pseudarthroses *Acta orthop scand* in press

Bassett, C A L & Creighton D K (1962) A comparison of host response to cortical autografts and processed calf heterografts. *J Bone Jt Surg* 44A 842–854

Bauermeister A (1958) Experimentelle Grundlagen fur den Aufbau einer neuen Knochenbank. *Hefte Unfallheilk* 58

Bauermeister A (1961) Die Behandlung von Zysten Tumoren und entzundlichen Prozessen des Knochens mit dem "Kieler Knochenspan" *Bruns Beitr Klin Chir* 203 287–310

Cohen J & Maletskos C J (1962) *Radioisotopes and Bone* pp 127–145 Blackwell Oxford

Fuchs G Stegemann H & Eger W (1963) Der transplantierte Knochenspan und seine Qualitat nach partieller und vollstandiger Enteiweissung bei erhaltener anorganischer Substanz *Langenbecks Arch Klin Chir* 303 240–260

Gattow G & Munzenberg K J (1963) Die organische und anorganische Fraktion des Kieler Knochenspans im rontgenographischen Bild. *Arch orthop Unfall chir* 55 453–461

Goff C W (1944) The os purum implant *J Bone Jt Surg* 26 758–767

Hallen L G (1966) Heterologous transplantation with kiel bone *Acta orthop scand* 37 1–19

Heiple, K Kendrick R E, Herndon C H & Chase S W (1967) A critical evaluation of processed calf bone *J Bone Jt Surg* 49A 1119–1127

Hopf A (1957) *Verhandl Dtsch Gesell Orthop* Pp 449–450

Hurley L A Zeier F G & Stinchfield F E (1960) Anorganic bone grafting *Amer J Surg* 100 12–21

Karges D E Anderson K J, Dingwall J & Jowsey J (1963) Experimental evaluation of processed heterogenous bone transplants *Clin Orthop* 29 230–247

Koch W (1957) Uber die Vitalisierung von implantierten Knochenspanen *Verhandl Dtsch Gesell Orthop* Pp 444–449

Maatz R (1967) *Dixième Congrès International de Chirurgie Orthopedique et de Traumatologie* Pp 659–665 Les Publications Acta Medica Belgica Bruxelles.

Maatz R & Bauermeister A (1957) A method of bone maceration *J Bone Jt Surg* 39A 153–166

Orell S (1934) *Studien uber Knochenimplantation* und Knochenneubildung Implantation von "os purum" sowie Transplantation von os novum" *Acta chir scand* 74 Suppl 31

Quigley M B & Hjørting Hansen E (1962) Crystal arrangement in anorganic bone *Acta odont scand* 20 359 366

Schilling H & Vockemann P F (1962) Klinische Erfahrungen mit einem heteroplastischen Knochenmaterial. *Bruns Beitr Klin Chir* 205 89–98

Witt, A N (1967) *Dixieme Congres International de Chirurgie Orthopedique et de Traumatologie* Acta Medica Belgica Bruxelles.

Acta orthop. Scandinav. 39, 708–720, 1968

Mayo Graduate School of Medicine, University of Minnesota, and Section of Surgical Research, Mayo Clinic and Mayo Foundation, Rochester, Minnesota, U.S.A.

A STUDY OF BONE FORMATION IN DOGS OF DIFFERENT METABOLIC STATES USING AUTORADIOGRAPHIC VISUALIZATION OF ^{45}Ca

VU VAN NGUYEN & JENIFER JOWSEY

Received ix.68

The evaluation of bone turnover using a bone biopsy technique is essentially a method that depends on taking a sample from a single area of the skeleton and comparing values for tissue formation and resorption with those from samples taken from the same area in another animal or individual. From the comparison inferences can be made of the relative metabolic status of bone tissue in the two animals. Bone sampling has been used to measure bone turnover in normal persons or animals of different ages and the information is used as a basis for comparison with abnormal material to allow characterization of the abnormality (*Barer & Jowsey* 1967, *Beck & Nordin* 1960, *Jowsey* 1966 b, *Jowsey et al.* 1965 a, *Lee* 1965, *Riggs et al.* 1965, *Smeenk* 1961, *Stanbury* 1961, *Villanueva et al.* 1966).

The validity of such a method depends on the assumption that a sample is representative of the rest of the skeleton. Although the values obtained from a single bone sample need not be identical with the values found in that tissue throughout the body, there should be high correlation between different sites. In this way, from a single biopsy specimen, a prognosis can be made regarding the metabolic status of the rest of the skeleton. The significance of differences between values depends on the variations found in normal material and within one sample.

This investigation was supported in part by Research Grant AM 8654 from the National Institutes of Health, Public Health Service.

Read at the meeting of the Orthopaedic Research Society, Chicago, 19 January 1968.

The purpose of this experiment was to study bone formation at different skeletal sites in dogs known to have different metabolic conditions and to find out if unpredictable variations between sample sites of the same animal or variations between normal animals are small enough (when compared with real differences between groups of animals having different metabolic activities) to allow a sampling technique to be a valid method for evaluating and comparing skeletal metabolism

MATERIALS AND METHODS

The experimental animal was the adult dog Roentgenographic evidence of closure of the epiphyseal plate was established before the dog was included in the experiment. Three groups were studied Group 1 consisted of five dogs that had been thyroparathyroidectomized 1 to 2 months before the beginning of the experiment (these dogs were expected to have low values for bone formation and resorption) Group 2 was the control group and consisted of five normal dogs and Group 3 consisted of five postparturition and postlactation female dogs (These animals were assumed to have a high bone turnover)

Radioactive calcium (^{45}Ca) was given intravenously in a single injection 50 to 200 $\mu c/kg$ body weight and the dogs were sacrificed 48 hours to 7 days later

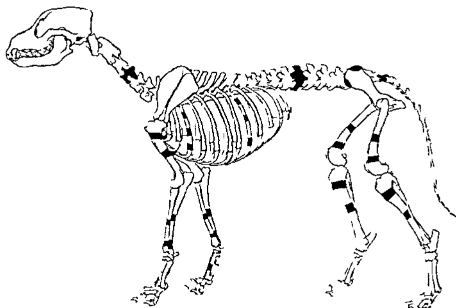


Figure 1 Skeletal sites studied in three representative dogs of different metabolic states

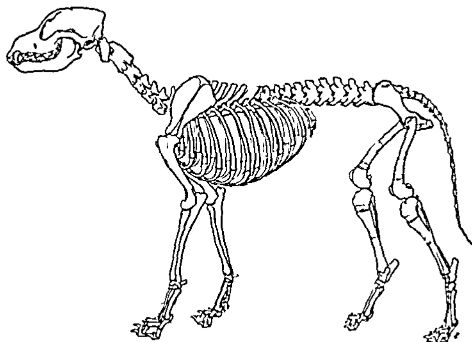


Figure 2 Skeletal sites studied in all dogs

From one dog in each group bone sections were taken from 33 different sites of the skeleton These samples were taken from representative areas of the body including both cortical and trabecular bone (spinal column ribs iliac crests long bones of the anterior and posterior limbs for details see Appendix and Figure 1) comparable samples were taken from the left as well as the right side of the body From the remaining animals in each group samples were taken only from the iliac crest rib and the diaphysis and metaphysis from both the femur and tibia (for details see Appendix and Figure 2) Since these sites were also studied in the three representative dogs they were common to all animals of the three groups.

The bone samples were embedded in methacrylate and three sections were cut from each bone sample (Jowsey et al 1965 a) The sections were exposed on type A autoradiographic plate long enough to produce an autoradiograph of suitable density After development magnified prints were made of the autoradiographs and the amount of bone formation was assessed from these pictures by measuring the areas of high uptake of ^{45}Ca Such areas were considered to represent the calcification of new bone and therefore to represent bone formation if the density was clearly greater than that of the diffuse uptake of ^{45}Ca Measurements were made in the following manner The number of small osteons showing concentrated uptake of ^{45}Ca were counted these are the so-called hot spots The length of all measurable surfaces with high density in the autoradiograph was assessed with a map measurer Previous data have shown that the average perimeter of an Haversian canal in dog is 100 μ (Jowsey 1966 a) Therefore the length of the active surface in all small osteons can be obtained by multiplying the number of hot

spots (N) by 100 μ. This figure was added to the length of all surfaces of high specific activity (L) and the sum represented the value for the length of all surfaces in that section undergoing bone formation. The area of the bone sample (S) was then measured with a planimeter and bone formation was expressed in terms of length per unit area of the section (mm/cm²) Thus

$$\text{Bone formation/unit area} = \frac{(N/10) + L}{S}$$

The values for the three sections were averaged, and the results between different skeletal sites in each animal different animals in each group and different groups were compared. The data were pooled from each similar skeletal site for computing correlations and the significance of differences for example iliac crest refers to values from the right and left anterior and the right and left posterior aspects of the iliac crest (see Appendix)

RESULTS

The autoradiographs of the sections of labeled bone showed distinct areas of high density In some skeletal sites such as the iliac crest and rib there was an obvious difference in the number of areas of concentrated uptake of ^{45}Ca (Figure 3)

Analysis of Bone Formation in the Three Representative Dogs in Each Group

Results obtained for bone formation per unit area were first compared between the three representative dogs in each group First 14 different pairs of data were compared a value from the right side and one from the left side in the same area in the bone constituting the two values in each pair The results show a high positive correlation between such pairs (Table 1)

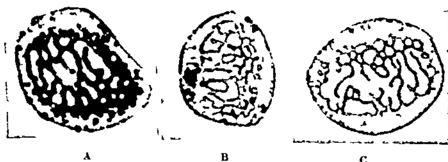


Figure 3 Autoradiographs of cross sections of a rib from each of three representative dogs in each group show variation in number of hot spots A Group 1 hyperactive B group 2 control C group 3 hypoactive (all × 11)

Table 1 Correlation from left to right sides in all sites in the three representative dogs

Dog	N	r	t	df
Hyperactive	14	0.9[illegible]0	8.133	12
Control	14	0.941	9.665	12
Hypoactive	14	0.973	14.634	12

Table 2 Bone formation per unit area in the three representative dogs

Dog	Spinal column†	Rib†	Iliac crest†	Long bones Diaphysis§	Long bones Metaphysis§
Hyperactive	116.0	153.0	142.0	43.7	57.9
	±40.0	±10.5	±13.0	±2.6	±7.6
Control	22.6	86.1	84.0	10.9	16.8
	±7.9	±7.3	±18.0	±2.5	±4.1
Hypoactive	15.8	22.2	30.4	6.7	10.3
	±5.5	±1.3	±5.6	±0.7	±0.7

Mean ± SE.

† Values represent pooled data from all sections in this site (see Appendix)

§ Diaphysis = pooled data from femur, tibia, humerus, radius, ulna and metatarsals; metaphysis = pooled data from femur, tibia, humerus, radius and ulna (see Appendix)

Next a comparison was made in these same three dogs between the amount of bone formation in different sites in the skeleton (Table 2). The rib and iliac crest consistently showed the highest activity in all three groups, whereas the long bone diaphysis, not surprisingly, showed the lowest activity in all three animals. Considerable differences were found in bone formation between the three animals; the ratio was as high as 4 to 1 between the hyperactive and the normal dog and up to 2.5 to 1 between the normal and the hypoactive dog. The t test was applied to paired data; each pair consisted of the bone formation value in the same skeletal site in the hyperactive and in the control dog, or in the hypoactive and control dog. The test establishes whether real differences exist between the different groups of animals, whatever site was chosen. The results in Table 3 show that in all skeletal sites the hyperactive dog was significantly different from the control dog (95 and 99 per cent confidence levels). In the

Table 3 Comparisons for similarity or dissimilarity between the three representative dogs

Skeletal site	N	Control versus hyperactive dog		Control versus hypoactive dog	
		T value	*P* value	T value	*P* value
Spinal column†	3	2.80	< .05	0.87	< .5
Rib†	4	6.03	< .01	9.93	< .01
Iliac crest†	4	3.02	< .05	3.28	< .05
Long bones					
Diaphysis§	12	9.49	< .01	1.70	< .1
Metaphysis§	10	5.01	< .01	1.68	< .1

With control group (t test)

† The data consist of pooled values for all sections in this site (see Appendix)

§ Diaphysis = pooled data from femur tibia humerus radius, ulna and meta tarsals metaphysis = pooled data from femur tibia humerus radius and ulna (see Appendix)

comparison between the hypoactive and the control dog the spinal column and long bones did not show significant differences the confidence levels were 50 and 90 per cent respectively However the rib and iliac crest showed a significant difference at the 95 and 99 per cent confidence levels respectively At all sites bone formation in the hypoactive dog was significantly less than that in the hyperactive dog

Analysis of Bone Formation in All Dogs in the Three Groups

An analysis was carried out in all dogs in the three groups in which bone formation in a single site was compared with other sites in the same skeleton The site chosen was the iliac crest This was compared with rib and tibial and femoral metaphyses and diaphyses The bone formation values demonstrated a small randomization frequency ($P < .01$) There was a high correlation ($r = 0.951$) between rib values and iliac crest values in the same animal (Figure 4) The bone formation values in the long bones showed a somewhat lower but nevertheless a high positive correlation the metaphyses had a higher correlation with iliac crest ($r = 0.826$ femur metaphysis $r = 0.827$ tibia metaphysis) than the diaphyses ($r = 0.780$ femur diaphysis $r = 0.737$ tibia diaphysis)

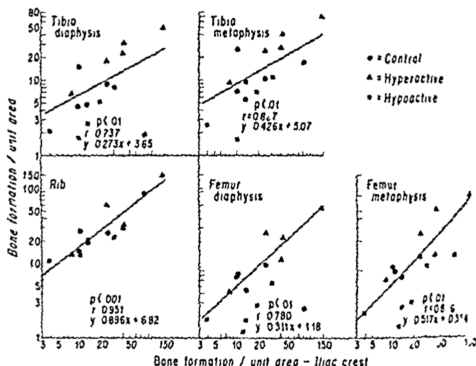


Figure 3 Correlation of bone formation at different skeletal sites in dogs in different metabolic conditions. Different sites are compared with the iliac crest. Note that data are plotted on log log paper

DISCUSSION

The use of ^{45}Ca as a label for the deposition of mineral in newly formed bone is now well established. Concentrated uptake of the isotope has been associated with unequivocal evidence of tissue depositions such as the presence of osteoid and double labeling with tetracycline (*Harris et al* 1962, *Lee et al* 1965, *Marotti & Marotti* 1965, *Marshall et al* 1959 a, *Marshall et al* 1959 b, *Strandh & Bengtsson* 1961). Careful autoradiographic studies of bone from animals killed at different times after injection of the ^{45}Ca have indicated that after 24 hours the majority of concentrated isotope deposition is associated with formation rather than short term exchange on surfaces (*Rowland* 1966). Therefore the basic premise of this report is valid. Concentrated deposition of ^{45}Ca occurs in areas of mineralization of new bone and linear measurements of such areas visualized autoradiographically are a measure of bone formation.

Evaluation of skeletal metabolism by biopsy methods rests on the

same assumption as many pathologic methods in which a small piece of tissue is examined and a diagnosis that refers to the whole organ is made The skeleton is unquestionably more variable in its metabolic activity from one area to another than most organs of the body Those variations that are found do not however have to be considered as sampling errors since these variations are predictable within reasonable limits from one site to another The results reported here show a good correlation between the different sites in the same skeleton ($r > 0\ 737$ for all sites studied) Therefore the same areas can be compared in different skeletons and if the relationship between the sites is known different sites in different skeletons can be compared Areas of low tissue turnover such as the diaphyses of long bones are unsuitable for evaluating conditions of low bone turnover such as hypoparathyroidism

The data obtained on rib material in these animals indicated that the rib is a valid site for biopsy because it showed clearly differentiated changes in different metabolic conditions that correlated well with the iliac crest This has not been the invariable experience with measurements of bone resorption in man particularly in older age groups possibly because the rib contains small amounts of bone tissue and ceases to represent the skeleton after a certain amount of tissue has resorbed (*Barer & Jowsey* 1967) In other skeletal areas the information obtained supports the conclusions derived from studies in man That the iliac crest containing a representative amount of cortical and trabecular bone is the most suitable area for biopsy (*Jowsey* 1966 b) whereas diaphyseal bone is the least active and only shows difference after intensive changes in metabolism

Previous investigations regarding the variations in bone formation in dogs have utilized the uptake of tetracycline *Amprino & Marotti* (1964) and *Jowsey et al* (1965 b) studied dogs ranging in age from 2 to 36 months and they showed large variations in bone formation from animal to animal However the results appeared to be consistently different and therefore predictable *Harris et al* (1967) have shown the importance of variations in the site of sampling in growing animals and it is evident that the error incurred in sampling in animals that are increasing in skeletal size or in the remodeling phase which follows the growth period is greater than in adult animals in which all bone turnover related to growth has ceased In this context *Amprino & Marotti's* (1964) data have indicated that a dog must be at least 18 months old before this state is achieved In our opinion

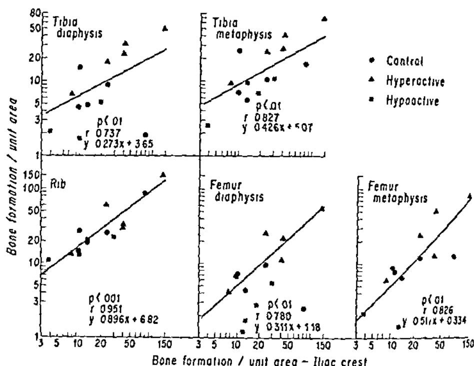


Figure 4 Correlation of bone formation at different skeletal sites in dogs in different metabolic conditions Different sites are compared with the iliac crest Note that data are plotted on log log paper

DISCUSSION

The use of ^{45}Ca as a label for the deposition of mineral in newly formed bone is now well established Concentrated uptake of the isotope has been associated with unequivocal evidence of tissue depositions such as the presence of osteoid and double labeling with tetracycline (*Harris et al* 1962 *Lee et al* 1963 *Marotti & Marotti* 1963 *Marshall et al* 1959 a *Marshall et al* 1959 b *Strandh & Bengtsson* 1961) Careful autoradiographic studies of bone from animals killed at different times after injection of the ^{45}Ca have indicated that after 24 hours the majority of concentrated isotope deposition is associated with formation rather than short term exchange on surfaces (*Rowland* 1966) Therefore the basic premise of this report is valid Concentrated deposition of ^{45}Ca occurs in areas of mineralization of new bone and linear measurements of such areas visualized autoradiographically are a measure of bone formation

Evaluation of skeletal metabolism by biopsy methods rests on the

and demonstrated the variations to be expected in such a group A variation was also found in the dogs reported on here However in order to evaluate the validity of a biopsy method it is necessary to find out if the values for bone formation found in known metabolic ally different skeletons are quantitatively different from the control values If such is true as has been shown in this report then a biopsy method is valid

A particular experience with human material may serve to illustrate the point Ribs from 12 persons with an unknown bone losing disorder were measured by the method of quantitative microradiography Values for age matched normal material were compared with these (Figure 5) The normal values fall clearly below those found in the meta bolically different group Although variations in normal material may be large they are smaller than the differences between the normal and the abnormal material

Harris et al (1967) also demonstrated variations in the width of new tissue deposition at different times and variations in the formation rate The method used in this study and also the question to be answered are concerned only with the number or dimensions of bone forming sites and not with rate

SUMMARY

Biopsy methods are based on the assumption that a sample of tissue is representative of that tissue throughout the body Such methods have been used to evaluate bone turnover in the skeleton The present study was *undertaken to examine this assumption To find if the* variations within individuals of a single metabolic state and the differences in the ratios between sample sites are small enough when compared with real differences in bone metabolism to justify the initial assumption

Three groups of adult dogs were studied the first group consisted of five dogs that had been thyroparathyroidectomized 1 to 2 months before the beginning of the experiment the second group consisted of five normal dogs and the third group consisted of five postparturition and postlactation dogs Bone formation was quantitated by means of autoradiography with Ca

The results indicate that the three groups differed significantly in levels of bone formation These differences were apparent in the skeleton of any one dog However each site had a relatively constant

ratio to all other sites Any variations from the left to the right side were within the limits that distinguished one group from another Only when bone turnover was low as in the midshaft of long bones in thyroparathyroidectomized animals was there a failure to distinguish between groups of different metabolic states

ACKNOWLEDGMENTS

The authors would like to thank Dr *B L Riggs* for his assistance in this project, and are grateful to Mr *Eldon Greenwaldt* and Mrs *Lucille M Stucky* for their technical help

REFERENCES

Amprino R & Marotti G (1964) A Topographic Quantitative Study of Bone Formation and Reconstruction *In Proceedings of the first European bone and tooth symposium Oxford April 1963* p 21 Macmillan Co New York.

Barer M & Jowsey Jenifer (1967) Bone formation and resorption in normal human rib bone A study of persons from 11 to 88 years of age *Clin Orthop* 52 241–247

Beck, J S & Nordin B E (1960) Histological assessment of osteoporosis by iliac crest biopsy *J Path Bact* 80 391–397

Harris W H Haywood Edith A Hamblen D & Lavorgna J (1967) Spatial and temporal heterogeneity of bone formation rates *J Bone Jt Surg* 49 A 793

Harris W H., Jackson R.H & Jowsey J (1962) The *in vivo* distribution of tetracyclines in canine bone *J Bone Jt Surg* 44-A 1308–1319

Jowsey Jenifer (1966 a) Studies of haversian systems in man and some animals. *J Anat* 100 857–864

Jowsey Jenifer (1966 b) Quantitative microradiography A new approach in the evaluation of metabolic bone disease (Editorial) *Amer J Med.* 40 485–491

Jowsey Jenifer Kelly P J Riggs B L Bianco A J Jr Scholz D A & Gershon Cohen J (1965 a) *J Bone Jt Surg* 47 A 785–806 8,2

Jowsey Jenifer Lafferty W & Rabinowitz J (1965 b) Analysis of distribution of Ca^{45} in dog bone by a quantitative autoradiographic method *J Bone Jt Surg* 47 A 359–370

Lee W R. (1965) A quantitative microscopic study of bone formation in a normal child and in two children suffering from osteogenesis imperfecta *In Proceedings of the second European symposium on calcified tissues Domaine Provincial de Wegimont March 31 to April 4 1964* p 451 Université de Liège Liège

Lee W R Marshall J H & Sissons H A (1965) Calcium accretion and bone formation in dogs An experimental comparison between the results of Ca^{45} kinetic analysis and tetracycline labelling *J Bone Jt Surg* 47 B 157–180

Marotti F & Marotti, G (1965) Validità dell impiego delle tetracicline nella valutazione quantitativa della formazione e del rinnovamento del tessuto osseo *Arch Putt* 20 394–409

Marotti G & De Lena M (1966) Analisi quantitativa dei processi di ricostruzione strutturale nella mandibola del cane in rapporto all etta. *Arch ital Anat Embriol* 71 229–252 Fascicle 3

Marshall, J H., Jowsey J & Rowland R. E. (1959 a) Microscopic metabolism of calcium in bone IV Ca^{45} deposition and growth rate in canine osteons. *Radiat Res* 10 243–257

Marshall, J H., Rowland R. E. & Jowsey J (1959 b) Microscopic metabolism of calcium in bone II Quantitative autoradiography *Radiat Res* 10 213–233

Riggs B L., Kelly P J Jowsy Jenifer & Keating F R. Jr (1965) Skeletal alterations in hyperparathyroidism Determination of bone formation resorption and morphologic changes by microradiography *J clin Endocr* 25 777–783

Rowland, R. E. (1966) Exchangeable bone calcium. *Clin. Orthop* 49 233–248

Smeenk, D (1961) Studies of bone of patients with hyperparathyroidism by means of phosphate exchange experiments *in vitro* and quantitative microradiography *J clin Invest* 40 433–444

Stanbury S. W (1961) Bone biopsy in the study of metabolic bone disease. *J Bone Jt Surg* 43 B 602

Strandh, J & Bengtsson A (1961) The uptake of calcium in microscopic bone structures in compact bone *Acta Soc Med upsalien* 66 95–103

Van der sluys Veer J., Smeenk, D & van der Heul R. O (1964) Tetracycline labelling of bone in hyperparathyroidism In *Proceedings of the first European bone and tooth symposium Oxford April 1963* p 85 Macmillan Co., New York.

Villanueva A R. Ilnicki L., Frost, H. M & Arnstein R. (1966) Measurement of the bone formation rate in a case of familial hypophosphatemic vitamin D resistant rickets. *J Lab clin Med* 67 973–982.

APPENDIX

I Skeletal sites studied in three representative dogs of different metabolic states.

A Spinal column.

1 C-4

2. L-2.

3 Second caudal vertebra

B Ribs

Right and left sides, third and eighth ribs (from each rib secti ns were taken at the middle of the middle third and at the junction of the middle third with the anterior and posterior thirds)

C. Iliac crests.

1 Right and left sides anterior iliac crest (1 cm behind anterior superior iliac spine)

2 Right and left sides posterior iliac crest (1 cm in front of posterior superior spine)

D Humerus, radius ulna right and left sides

1 Diaphysis (midway between two epiphyses)

2 Metaphysis (proximal metaphysis in the humerus and distal metaphysis in the radius and ulna)

D Tibia femur right and left sides
1 Diaphysis (midway between two epiphyses)
2 Metaphysis (distal metaphysis in the femur and proximal metaphysis in the tibia)
E Metatarsals second and fourth (midshaft and anterior right foot only)

II Skeletal sites studied in all dogs
A Iliac crest
1 Right and left sides anterior iliac crest (1 cm behind anterior superior iliac spine)
2 Right and left sides posterior iliac crest (1 cm in front of posterior superior iliac spine)
B Rib
Right and left sides third and eighth ribs (from each rib sections were taken at the middle third and at the junction of the middle third with the anterior and posterior thirds)
C Tibia femur right and left sides
1 Diaphysis (midway between two epiphyses)
2 Metaphysis (distal metaphysis in the femur and proximal metaphysis in the tibia)

Acta orthop Scandinav 40 721–728 1970

Surgical Department (Former Head Associate Professor Ralf V Lindholm M.D.)
Vaasa Central Hospital, Vaasa Finland

EFFECT OF FORCED INTERFRAGMENTAL MOVEMENTS ON THE HEALING OF TIBIAL FRACTURES IN RATS

Ralf V Lindholm T Sam Lindholm Sakari Toikkanen
& Ralli Leino

Received ix.68

Although veterinary medicine has dealt rather extensively with fractures in animals pseudarthrosis has been a neglected aspect of the matter Judging from the few reports pseudarthrosis rarely occurs in domestic or small animals In dogs sporadic cases of typical ball and socket non union have been radiologically verified and presented (e g Vaughan 1966) In a series of 142 fractures among unspecified carnivores and without any comment on treatment only one case was reported (Baumann & Scabell 1966) The reason for non union is thought to be inadequate fixation of the fragments while primary osteoblastic insufficiency is considered unlikely (Frost 1965)

Ordinarily non immobilized experimental fractures of the lower leg in the rat heal in 3–4 weeks During this period the rat moves freely and shows only slight signs of limping during the first few days Non union has not been observed Under abnormal conditions such as administration of cortisone or alimentary calcium deficiency non union has sometimes been known to occur

The purpose of this investigation was to study the effect of (Lindholm Lindholm Toikkanen & Leino preliminary report 1968) movements between the fragments of tibial fractures in rats The questions to be answered were (1) Can union be prevented by inducing repeated movements between the fragments and (2) What does the callus formation look like under such conditions?



Figure 1. Rupture of the skin and subcutis at the site of callus formation of a 47 day old experimental fracture in a rat subjected to daily interfragmental movement by manipulation.

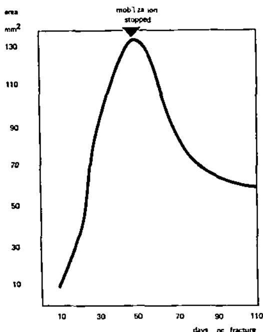


Figure 2 Effect of interfragmental movements on the callus area of experimental fractures in rats

MATERIAL AND METHODS

The material consisted of 30 Wistar rats averaging 130 g in weight at the start of the experiment. The animals had been reared under routine laboratory conditions. The right lower leg was manually fractured in ether narcosis Likewise in ether narcosis forced mobilization of the fragments was performed once a day beginning from the day of fracturing by manual bending in the sagittal plane at the site of fracture The degree of movements approximated 180 + 180 360

Radiographs were taken of the leg and the amount of callus estimated by planimetry on days 11 17 23 29 41 44 and 47 Forced mobilization was discontinued on day 47 Thereafter planimetric measurements were made from radiographs taken on days 4 7 18 21 25 28 32 35 58 75 and 102 after cessation of mobilization Samples were taken for histological examination

RESULTS

Mechanical Resistance to Mobilization

After daily manipulation for two weeks the fragments could not be brought into the maximum position of dislocation without using considerable force The process of mechanical stabilization proceeded

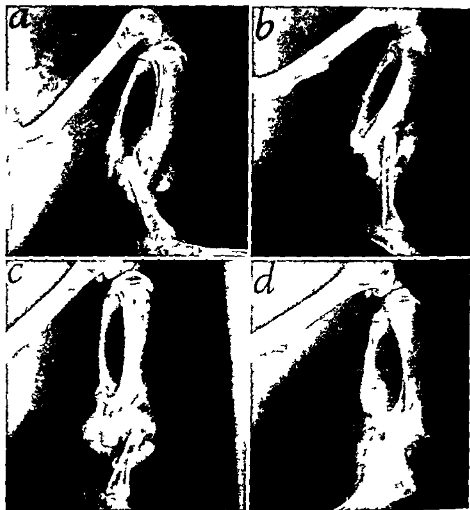


Figure 3 *Radiographs of experimental fractures of the lower leg in rats subjected to daily interfragmental movements by manipulation A day 11 B day 29 C day 41 D day 47*

rapidly and fragmentation of the callus before the required angle of movement was reached could not be avoided (Figure 3) After 7 weeks of experiment the callus exerted an almost insuperable resistance and had a mass which interfered with the overlying subcutaneous tissue and skin causing traumatic rupture at the point of the fulcrum (Figure 1) Since this meant complication of the fracture and the possibility of infection the fracture had to be left alone from day 48 on

The callus area reached its maximum at the time when movements ceased as estimated by planimetry (Figure 2) Regression soon took

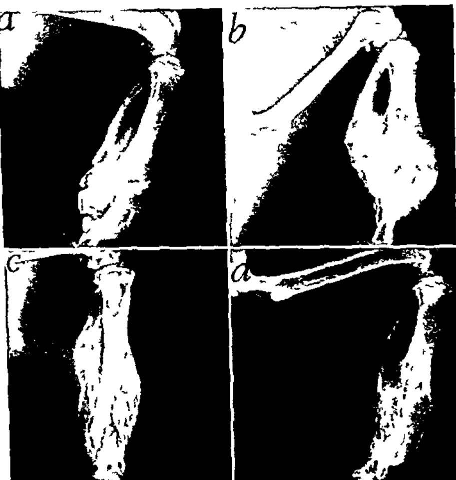


Figure 4 Radiographs of experimental fractures of the lower leg in rats following forced mobilization of the fragments for 47 days A day 51 after fracture 4 days after cessation of movements B 68/21 C 105/58 D 149/102

place the area approaching moderate proportions 20-25 days after cessation of mobilization

Mineralization of the entire callus took place very soon after cessation of movements (Figures 4A B) Re-organization of the callus appeared and resorptive processes caused relative osteoporosis (Figures 4C, D)

Tissue components of the callus Fibrous and hyaline cartilage dominated the picture to an overwhelming degree (90-95 per cent) until cessation of movements (Figure 5)



Figure 5 Microphotograph (× 400) shows predominance of cartilage in the callus of a 29 day-old tibial fracture subjected to daily forced movements between the fragments In unmanipulated controls the callus by that time had calcified entirely and the fracture had consolidated

Signs of non union Clinically resistance to mechanical trauma increased even though abnormal mobility was present until day 47 of the experiment Radiologically the typical socket and ball morphological sign of pseudarthrosis could not be observed (Figures 3C D)

In conclusion it may be stated that it is not possible experimentally to induce non union with typical pseudarthrosis in tibial fractures of the rat by daily forcing abnormal large movements between the fragments because of the enormously hypertrophied cartilaginous callus tumour which mechanically complicates the fracture through concomitant lesions of the soft tissue including the skin

DISCUSSION

That overstrain traction and pressure of tissues as suggested by Albertini (1929) Krompecher (1937) and Glücksmann (1939) are the prerequisites for and causes of chondrogenesis has been confirmed by Rissanen (1960) by his own observations on strong formation of cartilaginous tissue in combination with abnormal strains on fascial

tissue Acid mucopolysaccharides and strong metachromasia ... that this process is occurring.

A. W. F. Lettin (1967) has shown that entirely rigid fixation of fractures turns the endochondral osteoregeneration into a process like intramembranous (endosteal) ossification. Mast cells ... closely related to the metabolism of acid mucopolysaccharides ... according to recent observations by Lindholm & Lindholm ... occur in greater quantities in the periosteal (external) part ... endosteal (internal) part of the callus of non-immobilized ... rabbits

Such knowledge in combination with our experimental ... appear to justify the hypothesis that endochondral ... sents only a qualitative deviation from osteogenesis ... movements microtrauma and delay of mineralization ... chondral and intramembranous osteoregeneration ... sidered fundamentally different histogenetic processes ... may be a function directly correlated with the ... central part of the endosteal callus and the point ... under observation. To what extent this theory ... mechanism of osteogenesis during growth remains ... The theory reviewed by Ham & Harris (1951) that ... tissue forms where there is movement seems ...

SUMMARY

In order to gain further insight into the pathogenesis ... pseudarthrosis the effect of large interfragmental ... healing of tibial fractures was studied in the rat ...

The area of callus grows very large and ... tissues to such a degree that 17 days after the ... have to be discontinued. During this time ... could be created. Left on its own the callus ... zed and consolidates in a very short time ...

The extent to which chondrogenesis may ... gree of instability between the fragments ...

REFERENCES

Albertini A. (1929) ...

Baumann M. ... (1966) ... bei ... Berl ...

Frost, C (1965) The closed reduction and repair of radioulnar fractures in the dog *J small Anim Pract* 6 3

Glücksmann A (1939) Quoted by Rissanen P

Ham, A W & Harris W R. (1956) Repair and transplantation of bone. In Bourne's *Biochemistry and Physiology of Bone* p 488 New York Academic Press.

Krompecher S (1937) Quoted by Rissanen P

Lettin A W F (1968) The biological effect of rigid internal fixation on the healing of cortical bone. *J Bone Jt Surg* 50 B 227

Lindholm R & Lindholm S (1970) Mast cells in endosteal and periosteal bone repair A quantitative study on callus tissue of healing fractures in rabbits. *Acta orthop scand* 41 in press

Lindholm R Lindholm S Toikkanen S & Leino R. (1968) Experimentell undersokning av mobilisationens inverkan på benlakningen *Nord Med* 80 1603.

Rissanen P (1960) The surgical anatomy and pathology of the supraspinous and intraspinous ligaments of the lumbar spine with special reference to ligament ruptures. *Acta orthop scand* Suppl. 46 92

Vaughan L C (1966) Clinical study of non union fractures in the dog *Year Book of Veterinary Medicine* Vol 13

Acta orthop Scandinav 40 729-740 1970

Department of Orthopaedics Brasilia, Brazil

THE PHYSICAL PROPERTIES OF THE CORTICAL NECK OF THE FEMUR

ODILIO DA SILVA

Received 29.xi.68

Interest in the proximal end of the femur with regard to its mechanical value as a weight bearing system has been the subject of conjecture for many years in terms of its geometric arrangement of trabeculae following the descriptions of Bourgery (1832) and the theories of Ward (1838) Culmann (1866) and Meyer (1867)

Analysis of the forces acting upon the head and neck of femur under normal physiological conditions has been reported by many authors and has been reviewed recently by *Rydell* (1966) Since the magnitude and directions of these forces are not well known it is difficult to understand them from a mechanical point of view Stresses and strains in the femoral neck when loaded have been quantitatively analysed by means of the stress coat technique (*Kuntscher* 1935 *Evans Lissner & Pedersen* 1948 1949 1956) the photoelastic model (*Pauwels* 1948 1955 *Kummer* 1966) and strain gauges (*Hirsch & Frankel* 1960 1961)

In the laboratory the mechanical forces acting on this extremity with various types of loading and the reaction of the femoral neck to them have been studied under specific experimental conditions in the past (*Hirsch & Brodetti* 1956) and more recently under vital conditions (*Hirsch & Rydell* 1964 *Rydell* 1966)

Although the physical properties of most of the human compact bones have been studied by several authors studies on human cortical bone of the neck of femur have been restricted to studies by *Sedlin & Hirsch* (1966) who reported a few physical properties on the inferior portion of the cortical neck of the femur Since it is generally accepted that the stress distribution in the bone is dependent upon the structure

Special Research Fellow of *Conselho Nacional de Pesquisas, Rio de Janeiro* Brasil.

Table 1 Comparison between quadrants of femoral neck in different tests

Test	Quadrant	No of samples	Average for slope (P/a)	± S D	Average f prop limit (kp)	± S D	Average f max load (kp)	± S D	Average f max deform (mm)	± S D
Tension	Anterior	10	62 75	11 62	5 473	1 671	10 160	3 109	0 245	0 067
	Posterior	10	78 28	15 36	7 640	1 396	15 200	3 015	0 332	0 104
	Inferior	10	74 90	41 87	7 500	1 936	15 130	0 489	0 347	0 112
Bending	Anterior	10	1 361	0 301	0 423	0 103	0 879	0 207	1 225	0 348
	Posterior	10	1 757	0 339	0 552	0 068	1 136	0 090	1 575	0 548
	Inferior	10	1 497	0 290	0 515	0 069	1 045	0 100	1 535	0 290
Compression	Anterior	10	249 22	103 94	38 205	13 949	45 176	21 336	0 30[illegible]	0 163
	Posterior	10	275 90	107 23	34 241	14 306	40 864	22 310	0 296	0 171
	Inferior	10	357 40	130 35	45 635	17 544	67 580	23 320	0 417	0 184

Table 2 Statistical analysis of Table 1

Test	Physical properties	Anterior × Posterior t calc	$\lessgtr$	t tab	Anterior × Inferior t calc	$\lessgtr$	t tab	Posterior × Inferior t calc	$\lessgtr$	t tab
Tension	Slope	∣—3 825∣	>	2 26	∣—3 900∣	>	2 26	0 253		2 26
	Proportional limit	∣—4 418∣	>	2 26	∣—3 [illegible]61∣	>	2 26	∣—0 259∣	<	2 26
	Maximum load	∣—4 044∣	>	2 26	∣—5 978∣	>	2 26	∣—0 6[illegible]∣	<	2 26
	Maximum deformation	∣—3 [illegible]89∣	>	2 [illegible]	∣—3 743∣	>	2 26	∣—0 736∣	<	2 26
Bending	Slope	∣—2 883∣	>	2 26	∣—2 322∣	>	2 [illegible]6	—0 662	<	2 26
	Proportional limit	∣—3 7[illegible]∣	>	2 26	∣—4 927∣	>	2 [illegible]6	1 60[illegible]	<	2 26
	Maximum load	∣—6 547∣	>	2 26	∣—5 422∣	>	2 26	3 517	>	2 26
	Maximum deformation	∣—3 289∣	>	2 26	∣—3 743∣	>	[illegible] 26	0 698	<	2 26
Compression	Slope	∣—1 076∣	<	2 26	∣—2 576∣	>	2 26	∣—2 80[illegible]∣	>	2 26
	Proportional limit	1 401	<	2 26	∣—2 483∣	<	2 26	∣—2 446∣	>	2 26
	Maximum load	∣—0 333∣	<	2 26	∣—3 282∣	>	2 26	∣—[illegible] 712∣	>	2 26
	Maximum deformation	0 563	<	2 26	∣—2 684∣	>	2 26	∣—3 381∣	>	2 26

Table 3 Comparison between samples of same quadrant of the femoral neck

Test	Quadrant	No of samples	Average for slope (1/α)	± S D	Average f prop limit (kp)	± S D	Average f max load (kp)	± S D	Average f max deform (mm)	± S D
Tension	Anterior 1	5	63 45	11 97	5 875	1 651	10 962	2 630	0 269	0 048
	Anterior 2	5	61 96	12 11	5 014	0 539	9 242	3 556	0 218	0 078
	Posterior 1	5	83 96	10 60	8 528	0 736	16 071	2 705	0 328	0 099
	Posterior 2	5	73 31	17 74	6 862	1 398	14 437	3 238	0 335	0 116
	Inferior 1	10	72 89	12 [illegible]4	6 910	1 982	15 460	1 168	0 386	0 075
	Inferior 2	10	76 90	9 98	8 090	1 919	14 800	1 926	0 307	0 102
Bending	Anterior 1	4	1 375	0 237	0 451	0 168	0 927	0 175	1 323	0 340
	Anterior 2	4	1 3[illegible]6	0 471	0 355	0 114	0 760	0 257	0 979	0 252
	Posterior 1	5	1 886	0 347	0 530	0 036	1 120	0 091	1 236	0 440
	Posterior 2	5	1 709	0 344	0 561	0 077	1 142	0 095	1 702	0 553
	Inferior 1	6	1 490	0 185	0 518	0 059	1 033	0 085	1 477	0 321
	Inferior 2	6	1 504	0 170	0 511	0 082	1 057	0 118	1 593	0 265
Compression	Anterior 1	7	280 02	101 86	37 900	12 383	50 070	16 020	0 324	0 126
	Anterior 2	7	205 20	9[illegible] 96	29 500	13 461	33 730	14 005	0 279	0 115
	Posterior 1	7	266 25	86 53	29 375	11 553	44 163	17 457	0 247	0 137
	Posterior 2	7	3[illegible]2 26	125 11	38 567	15 743	56 489	25 683	0 340	0 195
	Inferior 1	10	3[illegible]1 [illegible]2	141 30	46 870	18 487	68 610	25 067	0 425	0 195
	Inferior 2	10	363 59	1[illegible]5 78	44 400	17 453	66 5[illegible]0	22 755	0 410	0 183

Table 4 Statistical analysis of Table 3

Test	Physical properties	Anterior 1 × Anterior 2 t calc	≤/≥	t tab	Posterior 1 × Posterior 2 t calc	≤/≥	t tab	Inferior 1 × Inferior 2 t calc	≤/≥	t tab
Tension	Slope	0 47	<	2 78	1 442	<	2 78	—0 960	<	2 26
	Proportional limit	0 905	<	2 78	1 553	<	2 78	—1 960	<	2 26
	Maximum load	0 953	<	2 78	1 738	<	2 78	0 857	<	2 26
	Maximum deformation	1 440	<	2 78	—0 035	<	2 78	1 983	<	2 26
Bending	Slope	| —0 365 |	<	3 18	0 424	<	4 74	1 044	<	2 57
	Proportional limit	| —0 770 |	<	3 18	0 144	<	4 74	0 867	<	2 57
	Maximum load	| —0 787 |	<	3 18	0 110	<	4 74	0 150	<	2 57
	Maximum deformation	1 726	<	3 18	0 700	<	4 74	| —1 740 |	<	2 57
Compression	Slope	1 [illegible]0	<	2 4	| —1 038 |	<	2 45	| —0 618 |	<	2 26
	Proportional limit	2 243	<	2 4	| —1 602 |	<	2 45	0 58[illegible]	<	2 26
	Maximum load	1 9[illegible]	<	2 4[illegible]	| —0 9[illegible] |	<	2 45	0 589	<	2 26
	Maximum deformation	0 943	<	2 45	| —0 887 |	<	2 45	0 566	<	2 26

Table 5 Comparison between

	Test	Tension						
	Quadrant	Anterior		Posterior		Inferior		Ante-
	Sex	♂	♀	♂	♀	♂	♀	♂
Physical properties	Slope (K/a)							
	Average	64 30	58 22	74 36	76 82	74 99	74 83	269 91
	± SD	10 18	9 84	6 72	18 99	5 90	10 56	83 30
	Proportional limit (kp)							
	Average	5 713	4 950	8 275	6 841	7 788	7 308	36 44(
	± SD	1 130	1 281	3 590	1 669	1 050	2 109	14 44:
	Maximum load (kp)							
	Average	11 188	8 883	14 375	14 825	14 700	15 416	48.60(
	± SD	2 703	2 464	1 161	4 060	2 640	1 3?6	22 577
	Max deformat. (mm)							
	Average	0 265	0 220	0 3?6	0 320	0 334	0 356	0 315
	± SD	0 051	0 100	0 050	0 100	0 024	0 083	0.183

ANALYSIS OF RESULTS

In order to establish the magnitude of allowable stresses bone specimens were tested up to failure in tension, compression and bending under static loading which gave different curves for increasing loads In all tests a curve was obtained The curves were not geometrically identical but they were quite similar

As can be seen in Figure 2 strain increases in direct relation to stress up to point A where the curves bend assuming a parabolic characteristic The stress corresponding to point A is called proportional limit If stresses do not exceed the proportional limit the elastic properties of the material remain intact i e after unloading the specimen recovers its original form and dimension consequently Hooke s law holds up to the proportional limit If the load is further increased deformation also increases up to point L when the stress reaches the maximum value that the specimen can withstand this is called maximum load After this point the curve falls rapidly force and conventional stress diminishes and rupture of the specimens takes place *The distance between point* Σ *and zero stress is the* maximum deformation

The results are summarized in Table 1 There is a relationship

...exes in differents quadrants

Compression						Bending					
...ior	Posterior		Inferior			Anterior		Posterior		Inferior	
♀	♂	♀	♂	♀		♂	♀	♂	♀	♂	♀
[illegible]05 3[illegible]	291 93	255 14	316 75	[illegible]87 31		1 448	1 240	1 708	1 835	1 721	1 450
40 52	40 33	79 0[illegible]	79 54	95 21		0 181	0 170	0 [illegible]37	0 563	0 469	0 137
37 600	31 730	34 083	41 120	38 367		0 459	0 388	0 551	0 563	0 529	0 492
14 465	65 86	107 77	7 496	22 66		0 033	0 108	0 060	0 100	0 062	0 053
40 000	48 4 0	49 417	61 100	60 133		0 904	0 852	1 133	1 127	1 056	1 017
11 127	7 800	15 [illegible]64	19 767	25 172		0 088	0 131	0 101	0 120	0 109	0 041
0 285	0 295	0 298	0 407	0 393		1 182	1 304	1 540	1 772	1 501	1 589
0 100	0 099	0 113	0 236	0 182		0 185	0 216	0 334	0 952	0 126	0 484

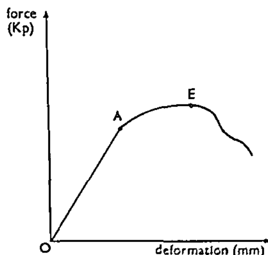


Figure 2 Stat[illegible]c load curve pro[illegible]uced by [illegible] The [illegible]urve [illegible] proportional limit at p[illegible]int A the maximum [illegible] and the maxi[illegible]um deformation fr[illegible]m th[illegible]s p[illegible]int at zer[illegible] stress in [illegible]

Table 6 Statistical analysis of Table 5

Test	Physical properties	Anterior t calc	$\lessgtr$	t tab	Posterior t calc	$\lessgtr$	t tab	Inferior t calc	$\lessgtr$	t tab
Tension	Slope	| −0.851 |	<	2.31	3.141	>	2.31	| −0.026 |	<	2.31
	Proportional limit	| −0.963 |	<	2.31	0.001	<	2.31	| −0.415 |	<	2.31
	Maximum load	| −1.396 |	<	2.31	0.001	<	2.31	0.001	<	2.31
	Maximum deformation	| −0.833 |	<	2.31	| −0.136 |	<	2.31	0.606	<	2.31
Bending	Slope	| −1.704 |	<	2.31	0.376	<	2.57	| −0.960 |	<	2.31
	Proportional limit	| −1.11 |	<	2.57	0.272	<	2.31	| −1.193 |	<	2.31
	Maximum load	| −0.825 |	<	2.31	| −0.030 |	<	2.31	| −0.619 |	<	2.31
	Maximum deformation	0.938	<	2.31	0.411	<	2.[illegible]7	0.310	<	2.[illegible]7
Com pression	Slope	| −1.230 |	<	2.45	| −0.895 |	<	2.45	| −0.473 |	<	2.4[illegible]
	Proportional limit	0.001	<	2.26	0.3	<	2.45	| −0.001 |	<	2.57
	Maximum load	| −0.61 |	<	2.45	0.11	<	2.45	| −0.001 |	<	2.45
	Maximum deformation	| −0.2[illegible] |	<	2.45	0.039	<	2.45	| −0.087 |	<	2.45

between physical properties of compact bone and quadrants from which the bone strips were cut

An analysis of the behaviour of specimens according to quadrant of femoral neck from which they came revealed that the stiffness of compact bone increases progressively from the anterior to the posterior and the inferior quadrants The same was true for its elastic properties

Comparison of the physical properties of specimens from different quadrants was made and the results were subjected to statistical study

Table 2 summarizes the results In tension test for all physical properties it was found that

$$A < P, A < I \text{ and } I = P$$

In bending test the results are similar to tension test for slope proportional limit and maximum deformation but for maximum load

$$A < P \quad A < I \text{ and } I < P$$

In compression test the results were

$$A = P \quad A < I \text{ and } I > P$$

for slope maximum load and maximum deformation For the proportional limit

$$A = P \quad A = I \text{ and } I > P$$

Since this study included one or more specimens from the same quadrant it is important to establish whether or not the differences between these specimens were significant The results are summarized in Table 3

One hundred and eighteen samples were used and tested until failure in compression bending and tension tests Specimen groups consisted of two specimens from each quadrant of a femoral neck of each subject It can be seen from Table 4 that the modulus of value calculated is not statistically significant Thus it may be concluded that there are no significant differences between specimens from each quadrant for the parameters measured

The influence of sex on the physical properties was also investigated Comparison of the mean values for the various physical properties was also investigated Comparison of the mean values for the various physical properties of specimens from each individual (Tables 5 and 6) shows that there is no definite and consistent change associated with sex

SUMMARY

The physical properties of the cortical neck of the femur have been evaluated in 218 specimens by means of tension compression and bending tests This study demonstrates that the stiffness and the elastic properties of the cortical neck of the femur increase progressively from the anterior to the posterior and inferior quadrant There is no significant difference between specimens of the same quadrant and sex

REFERENCES

Bourgery J M. (1832) *Traité Complet de l Anatomie de l homme* C A Delaunay Paris

Culmann C. (1866) *Die graphische Statik* Zurich

Evans F G & Lissner H R. (1948) Stresscoat deformation studies of the femur under static vertical loading *Anat Rec* 100 159–190

Hirsch C & Brodetti A (1956) The weight bearing capacity of structural elements in femoral necks *Acta orthop scand* 26 15–24

Hirsch C & Frankel V H (1960) Analysis of forces producing fractures of the proximal end of the femur *J Bone Jt Surg* 42 B 633–640

Hirsch C & Frankel V H (1961) The reaction of the proximal end of femur to mechanical forces In *Biomechanical studies of the musculo skeletal system* ed. F G Evans C C Thomas Springfield Illinois pp 66–80

Hirsch C & Rydell, N W (1965) Forces in the hip joint. In *Biomechanics and related bio engineering topics* (Proc. of a symposium held in Glasgow Sept. 1964) Pergamon Press pp 341–357

Kummer B (1966) Photoelastic studies on the functional structure of bone *Folia biotheor* 6 31–40

Kuntscher G (1935) Die Bedeutung der Darstellung des Kraftflusses in Knochen fur die Chirurgie *Arch Klin Chir* 182 489–551

Lissner H R & Evans F G (1956) Engineering aspects of fracture *Clin Orthop* 8 310–322

Meyer H G (1967) Die Architektur der Spongiosa *Arch Anat Physiol Wiss Med* 615–618

Pauwels, F (1948) Bedeutung und kaudale Erklarung der Spongiosaarchitektur in neuer Auffassung *Klin Wschr* 26 123–124

Pauwels F (1955) Über die Verteilung der Spongiosadichte im coxalen Femurende und ihre Bedeutung fur die Lehre vom funktionellen Bau des Knochens *Gegenbaurs morph Jb* 95 35–54

Pedersen H E Evans F G & Lissner H R. (1949) Deformation studies of the femur under various loadings and orientations *Anat Rec* 103 159–185

Rydell N W (1966) Processes acting on the femoral head prosthesis A study on strain gauge supplied prostheses in living persons *Acta orthop scand* Suppl. 88

Sedlin E. & Hirsch C (1966) Factors affecting the determination of the physical properties of femoral cortical bone *Acta orthop scand* 37 29 48

Ward, F O (1838) *Outlines of human osteology* H Renshaw London

Acta orthop Scandinav 40 741–750 1970

Department of Orthopaedics (Head O Lindahl)
Gefle Central Hospital Sweden

EXPERIMENTAL MUSCLE PAIN PRODUCED BY CHEMICAL STIMULUS

OLOV LINDAHL

Received 17 1 69

The view that pain has a metabolic and chemical origin has in recent years been presented mainly by Lewis and his colleagues (Lewis et al 1931 Lewis 1932 1946) who on the basis of a number of experiments on muscle pain concluded that this reaction especially in ischaemia is due to a chemical substance which he designated the P factor (pain factor) Lewis found that this hypothetical substance was diffusible was rapidly carried away in the bloodstream was produced in anaerobic muscles and was affected by changes in the acid base balance of the body Supply of bicarbonate delayed the occurrence of pain and supply of ammonium chloride accelerated its onset He did not arrive at any conclusion as to the nature of this chemical factor

From experiments in which various solutions were injected into muscles von Gaza & Brandi (1926) concluded that there was a close relationship between the pain in the muscle and the pH of the solution Alkaline or neutral solutions did not produce pain whereas acid solutions especially at a pH as low as 5 9 elicited almost insupportable pain Maison (1939) performed a similar series of experiments in which a number of substances were tested and in particular solutions of potassium salts and ones with different osmotic pressures The pain responses elicited by the various solutions were quite different from those reported by von Gaza & Brandi for instance in 25 per cent of the subjects isotonic saline elicited pain Injection of potassium salt solutions having a potassium ion concentration above 200 mg per 100 ml consistently produced a pain reaction In a few cases he examined the effect of acid solutions but did not always evoke pain even with a pH of 4 8 (one experiment) At a lower pH however pain was regularly elicited As in his view the pH interstitially in the muscles cannot fall below 6 5 he concluded that muscle pain is not due to an

increase in the hydrogen ion concentration but that potassium ions might be the factor responsible for the pain

Hypertonic solutions regularly produce pain as has been demonstrated by among others Kellgren (1939)

In an investigation published in 1961 Lindahl evoked skin pain in volunteer subjects by injecting a number of substances by a standardized technique he found that it was possible to determine the concentration of the various substances at which pain was elicited It was established that a rise in the hydrogen ion concentration was the sole factor that could produce pain at concentrations that can occur in the body and it was concluded that *pain—at least cutaneous pain—is due* to a metabolic disturbance that involves a local acid tissue reaction These studies on cutaneous pain were followed by a number of experiments on muscle pain an account of which is given below

METHODS

The experiments were performed on volunteer subjects of both sexes aged 23 to 55 years Some of them were included in the series for the cutaneous pain In a series of injections in which a comparison was made of the same test solutions 10–15 subjects were used. Further injections were made in a number of patients.

The test solutions were injected in both biceps brachii approximately in the middle of the upper arm and at least 1 cm into the actual *belly of muscle* The skin was anaesthetized by a small intracutaneous wheal through which a 0 6 mm needle was inserted into the muscle In the *occasional case* in which this procedure was accompanied by pain the injection was delayed until it had disappeared. A series of up to 10 injections of the various test solutions was given to each subject through the same wheal between each injection the needle was moved to new portions of the muscle by withdrawing it subcutaneously and inserting it into a new area along a conical surface Each solution was thus tested in 10 15 subjects It was compared with 5–9 other solutions on the same occasion By testing in both arms 20–30 test responses to each solution were obtained

In preliminary tests different volumes of solution were injected and it was found that smaller amounts (less than 0 5 ml) elicited an unreliable and varying pain response even in the case of solutions that were known to produce pain (such as 6 per cent saline) When large volumes were used (more than 2 ml) the actual injection could result in pain even with inert solutions (*isotonic saline*) The risk of diffusion to adjacent injection sites was of course greater the larger the volume, and for this reason the amount used was limited to 1 ml The *injection* was given over 5–10 seconds An almost instantaneous injection might sometimes cause pain solely by virtue of the rapid *injection rate*

The pain intensity was graded by the subjects according to a 6 point scale, from 0 to 5 A more detailed account of the evaluation technique has been given in an earlier paper (Lindahl 1961) The method used in this study was identical with that

in the testing of cutaneous pain except that the injections were now given intramuscularly

The statistical analysis of the values yielded by the test was performed in the same way as in the earlier study There the pain evoked had been assessed on the basis of its intensity and the duration but as these two parameters were found to be largely parallel, in the present study only the intensity was recorded another reason for this was that the duration of muscle pain was extremely long especially after the injection of solutions capable of producing severe pain and the pain sometimes recurred after having once disappeared The variability of the duration and spread of pains was considerably greater for intramuscular than intracutaneous injection.

The following test solutions were examined distilled water (osmotic pressure 0) saline with an osmotic pressure of 0 2 0 4 0 6 0 8 1 0 2 3 4 5 and 6 times greater than that of blood isotonic neutral solutions containing 5 18 32 45 59 72 and 99 mN of potassium ions and isotonic buffer solutions of pH 10 6 9 6 8 6 7 6 7 3 6 2 6 6 5 1 4 6 4 1 3 6 and 3 2 Exact data on the composition of the solutions and their physical properties are to be found in the previous paper (Lindahl 1961)

RESULTS

Solutions with Different Osmotic Pressures

This series of experiments was performed on 11 subjects and 10 different solutions of sodium chloride with osmotic pressures from 0 to 6 times that of the blood From the results reported in Figure 1 it

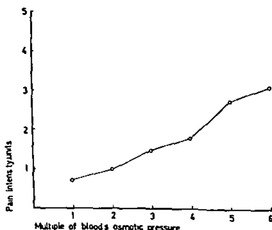


Figure 1 The relation between pain intensity and the rise in the osmotic pressure Each point on the curve corresponds to the mean pain intensity for 22 injections in 11 subjects The test solutions had an osmotic pressure from isotonia to 6 times the osmotic pressure of the blood

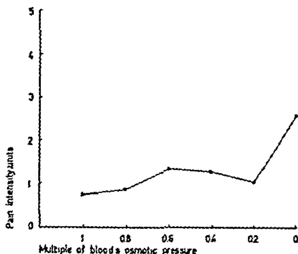


Figure 2 The relation between pain intensity and the lowering of the osmotic pressure Each point on the curve corresponds to the mean pain intensity for 22 injections in 11 subjects The test solutions had an osmotic pressure from isotonia to 0

is seen that the pain intensity associated with isotonic solutions increased parallel with the osmotic pressure There was a statistically significant correlation between the increase in osmotic pressure and the pain intensity ($0.001 < P < 0.01$) The rise was about the same as for the intracutaneous injections but the intensity was not so high and the range was considerably greater On lowering the osmotic pressure below isotonia a varying increase in pain intensity was obtained (Figure 2) but no significant correlation was found There was a significant difference between the pain level for distilled water and isotonic saline ($0.001 < P < 0.01$) The level recorded for isotonic saline was lower than that obtained in any of the series with intracutaneous injections

Solutions with Different Potassium Ion Contents

In this series 15 subjects were tested with 8 isotonic solutions the potassium ion content of which ranged from 5 to 99 mN The pain intensity increased parallel with this parameter (Figure 3) and the correlation was significant ($0.001 < P < 0.01$) As in the case of the hypertonic solutions the range was large and greater than for the intracutaneous tests and the pain intensity was lower for the intramuscular than the intracutaneous injections

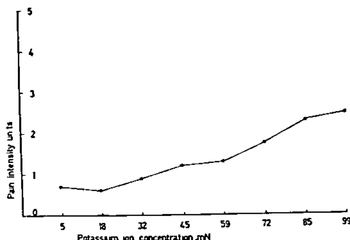


Figure 3 The relation between pain intensity and the potassium ion concentration Each point on the curve corresponds to the mean pain intensity for 30 injections in 15 subjects The test solutions were neutral and isotonic and their potassium content ranged from 5 to 99 mN

Alkaline buffer solutions

In this series 10 subjects were tested with 5 solutions having pH ranging from 10 6 and to 7 3 On increasing the hydroxyl ion concentration the pain response was slightly higher but showed appreciable variation (Figure 4) No significant correlation was obtained nor were there significant differences in pain intensity between the solutions

Acid Buffer Solutions

In this series 15 subjects were tested with 8 solutions ranging in pH from 7 3 to 3 2 There was an increase in pain intensity with the hydrogen concentration (Figure 5) and the correlation was significant (0 001 < P < 0 01) There was likewise a significant difference in the comparison between pH 7 3 and 5 6 (0 001 < P < 0 01)

Side Reactions and Effects on Patients

The tested subjects were all in sound health with no pain in the arms or legs The pain reaction to the intramuscular injections usually localized to the site of the injection but quite often there a tendency for spread throughout the arm and for the pain to ass a more diffuse character Unlike the sharp distinct and "

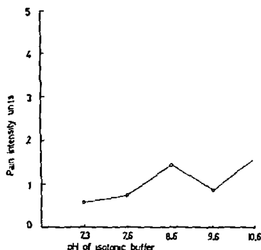


Figure 4 The relation between pain intensity and the increase in the hydroxyl ion concentration Each point on the curve corresponds to the mean pain intensity for 20 injections in 10 subjects The pH of the test solutions ranged from 7.3 to 10.6

scribed cutaneous pain muscle pain is of an unpleasant dull and protracted nature and in the cases in which it was prolonged and intense and where it spread in the arm it sometimes affected the general status producing a tendency for malaise or sweating In some cases injections after a number of hours or even after an interval of up to

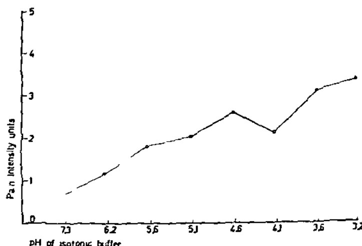


Figure 5 Relation between the pain intensity and the increase in the hydrogen ion concentration. Each point on the curve corresponds to the mean of 30 injections in 15 subjects The pH of the test solutions ranged from 7.3 to 3.2

one day gave rise to radiating pain in the arms and fingers that was reminiscent of ordinary brachialgia. After the injections there was usually definite and sometimes marked tenderness to pressure in the area of the injection and a marked reduction in the gross power in the flexors of the elbow These two features showed a largely parallel development and almost invariably disappeared within 24 hours

In 5 subjects injections (acid buffer solutions) were also given to patients admitted for lumbago and/or sciatica and brachialgia In these cases only a few (2-5) injections were given in one arm. The object was to examine whether these patients reacted more intensely than normal subjects to pain producing stimuli – that is to say whether the pain threshold to chemical stimuli in the muscles had been lowered In these few experiments there was no reliable evidence that this was the case but a number of other unexpected side effects were observed these taking the form of an exacerbation of the patient s "ordinary pain In 2 of the 3 cases where the patients suffered symptoms from the cervical spine including brachialgia there was intensification of this symptom throughout the arms and extending up to the neck and the head In one case the pain spread over to the other arm The pain elicited in this way was identical with that which the patient normally experienced though it was considerably more intense In another case it decreased over a period of 48 hours and in a third one the pain persisted for a week with short intervals of respite before the normal state was recovered In 2 patients with lumbar pain and/or sciatica marked brachialgic symptoms were produced and the sciatica was also rendered more acute The symptoms lasted a couple of days before the pains disappeared One of the subjects with sciatica had had brachialgic pain some years earlier and forgotten it when it recurred after the injections he remembered his old symptoms and recognized the type and area affected

The effects were so pronounced and uncomfortable that a more systematic study with these pain producing technique was not considered advisable

DISCUSSION

The chief aim of these experiments was to ascertain whether cutaneous and muscle pain are elicited chemically in the same way Although the tests for muscle pain were less extensive than for cutaneous pain it may be concluded that the former is elicited by the same stimuli as

the latter The concentrations required to evoke muscle pain were higher, however The sensitivity to chemical pain stimulus was lower for muscle than that for skin or, otherwise stated for muscle the pain intensity was lower for the same stimulus As in the case of cutaneous pain the only tested factor that produced pain under conditions of concentration that can occur in the body was an increase in hydrogen ion concentration It would thus seem highly probable that muscle pain too is elicited by a rise in the hydrogen ion concentration This view is consistent with the observations reported by Lewis and co workers on ischaemic muscle pain (Lewis et al 1931 Lewis 1932 1946) and in close agreement with the results of the studies on pH in exercised muscles

Whereas the pH interstitially in the muscles is normally about the same as that of the blood, the hydrogen ion concentration during exercise increases greatly and the pH can fall to 5 8 Exercise during ischaemia causes the hydrogen ion concentration to increase further (Dawson & Bodansky 1931) There are no sensory nerves interstitially in the muscles but it may be supposed that pain is elicited *via* such nerves in the vessels Because the protones that are formed during exercise diffuse directly from the muscle cells to the capillaries, and only to a small extent emerge into the interstites the hydrogen ion concentration is probably higher in the capillary walls than interstitially An impression of the hydrogen ion concentration in this region might possibly be obtained by measuring the intracellular muscle pH during exercise Caldwell (1956) and Moore et al (1931) have reported values down to pH 5 0

The lower sensitivity of the muscles than the skin to chemical pain stimulus may be ascribed to the fact that the skin is considerably more richly supplied with nerves and that the sensory nerves in the muscles are located in the actual vessel walls and not as in the skin interstitially where in any case a depot of the injected solution at first forms The greater variability in the pain response in muscle is probably due to identical factors and in consequence, contact between the injected liquid and the vascular nerves may vary quite widely depending on where the liquid is deposited

That intra arterial injections produce peripheral pain is known from the studies by Dawson et al (1931) who showed that pain was produced at as high a pH as 6 0

Maison s (1939) injection experiments in a small number of subjects in whom he sometimes failed to evoke pain on injecting solutions

at pH 4.8 into muscle cannot be considered to contradict the present results. As the volume injected was only 0.3 ml and his solutions were not buffered a regular pain effect is hardly to be expected. Nonetheless it is to be noted that he elicited weak pain in 2 of the 3 subjects. Owing to the buffering effect of the tissues and blood, and because the volumes were small the injected solutions rapidly lost their original hydrogen ion concentration.

The side effects observed in the patients and some of the subjects including the appearance of typical brachialgia after pain stimulus in the biceps tend to confuse the discussion of how brachialgic pain arises. It is at present commonly considered that this pain is elicited by stimulation of the segmental nerves.

Pain of this nature can clearly be elicited in several ways however and this must be seen in relation to what we know about referred pain multiple stimulus of spinal nerve cells above a certain threshold etc. It is however not the author's intention here to discuss the origin of brachialgic pain.

SUMMARY

In several series of 10–15 subjects the author injected various test solutions intramuscularly to examine how muscle pain is elicited by chemical stimuli.

It was found that muscle pain was evoked by the same chemical stimulus as produced cutaneous pain in a previous study. The pain response to the same concentration of the test substance was more variable and weaker for the muscle than for cutaneous pain. As in the case of the latter a rise in hydrogen ion concentration was the sole factor producing muscle pain under conditions of concentrations occurring in the body. It was concluded that a metabolic change resulting in tissue acidosis is the most likely cause of muscle pain and this is discussed in the light of previous research.

REFERENCES

Caldwell P (1956) *Int Rev Cytol* 5 229–277
Dawson W & Bodansky O (1931) *Proc Soc exp Biol* 28 635–636
Freunder H (1949) *Pflugers Arch ges Physiol* 251 631–638
Gaza von & Brandi B (1926) *Klin Wschr* 5 1123–1127
Kellgren J (1939) *Clin Sci* 4 35–39
Lewis, T (1932) *Arch intern Med* 49 713–727

Lewis T (1946) *Pain* Macmillan Co New York
Lewis T Pickering G & Rotschild P (1931) *Heart* 15 359-383
Lindahl O (1961) *Acta physiol scand* 51 Suppl 179
Maison G (1939) *Amer J Physiol* 127 315-321
Meyerhof O & Lohman K (1926) *Biochem Z* 168 128-165
Moore, R Moore R & Singleton A (1934) *Amer J Physiol* 107 594 602

Acta orthop Scandinav 40 751–764 1970

Department of Orthopaedic Surgery (Head Carl Hirsch) University of Gothenburg Sweden and Laboratory of Experimental Pathology (Head J P Kulka) R B Brigham Hospital Harvard Medical School Boston U S A

THE SYNOVIAL MICROVASCULAR DERANGEMENT IN RHEUMATOID ARTHRITIS AND OSTEOARTHRITIS

Ian Goldie

Received ix.68

The vascular involvement in rheumatoid arthritis has over the past years taken an important place in the interpretation of the pathomorphologic picture of synovial tissues The dominating feature is appreciated as a vasculitis localized to venules and capillaries (Kulka 1959) but arterioles also become involved though to a lesser degree (Sokoloff 1963) An interesting observation is the patchy distribution of these changes (Branemark et al 1963) Connective tissue adjacent to synovial tissue with rheumatic changes may have a capillary system which appears quite normal in structure and function (Branemark et al 1963)

Focal arteritis has been claimed of some importance in rheumatoid arthritis (Sokoloff 1953 1963) but according to Cruickshank (1954) arteritis is not common in articular lesions and the absence of arterial involvement where prominent synovial necrosis is observed has been pointed out by Kulka (1955) In fulminant disease however a necrotizing arteritis and arteriolitis can occur More recently it has become evident in light microscopic investigations that an irregularly distributed vasculitis involving venules and capillaries is a factor which may cause synovial tissue changes in rheumatoid arthritis Inflammation is noted in some venules associated to a varying degree with fibrin thrombosis and deposition of similar fibrinous material within the vessel walls and surrounding tissue Venular and capillary dilation occur in varying degree and an uneven outline of the venular bed and capillary network is observed Exudative leakage follows and circumstantial evidence points to a decreased flow velocity almost to the point of complete stagnation of corpuscular flow (Kulka 1955 1959)

This vascular reaction is not pathognomonic of rheumatoid arthritis. Observations indicate that other conditions, whether of exogenous or of endogenous origin, cause an identical vascular behavior. It has, e.g., been proved that cold induced vasospasm is capable of producing not only connective tissue proliferation and necrosis but also a segmental vasculitis (Kulka 1959, 1961). Similar microvascular dysfunction has been observed in psoriasis, serum sickness, and also in lesions produced by vasospastic agents. It thus appears, with certain limitations, that the reactivity of the vascular bed in synovial and connective tissues to various stimuli is non-specific and usually follows a well designed pattern in which the changes in the vessel walls stand out as predominant features.

Elmore et al. (1963) believe that hyaline sclerosis of minute vessels may cause a vascular insufficiency which ultimately ends in degeneration of articular cartilage and synovial tissues. This observation, however, is recognized as a common focal finding in joints, including those of young individuals, and does not directly relate to osteoarthritis (Hollander 1966). It could, on the other hand, be interpreted as a precursor to the final stage of bone-cartilage destruction.

In malum coxae senilis synovial hypertrophy is observed and connected with this, severe chronic inflammatory infiltrates. The histologic picture including the vascular features can appear indistinguishable from rheumatoid arthritis of joints such as the hip (Hollander 1966). Grueter & Rutt (1962) have carried out a morphologic study on joint changes in osteoarthritis. The joint capsules from twenty five hip joints of varying ages with osteoarthritis were examined. Macroscopically the synovial tissues were markedly edematous with a coarse surface and intense villous hypertrophy. They stated that the tissues appeared inflamed with the greatest intensity adjacent to the areas of capsule degeneration. On microscopic examination the synovial tissue showed signs of chronic non-specific inflammation with large edematous areas. Perivascular lymphocytic infiltrates were encountered. There was increased vascularity and the number of capillary buds was large. The capillaries very often pursued a corkscrew like course and a glomerular like arrangement was often obvious terminally. The same corkscrew appearance was noted in venules. All vessels, excluding arteries and arterioles, were dilated and appeared in a so called hypostatic condition. No endangiitis nor obliterating processes were observed. The vascular walls, however, were edematous.

Though the disease concept of rheumatoid arthritis is far remote

from that of osteoarthritis the two entities have the joints in common as target organs for destructive changes the background of which as yet is not clearly understood The local sequence of microcirculatory events in rheumatoid arthritis may act as a pathogenetical factor in joint destruction but little is known as to whether similar microcirculatory dysfunction may act as a pathophysiologic background to the deleteri ous involvement of cartilage bone and periarticular tissues in osteo arthritis By using special freeze fixation techniques (Kulka 1964) translucent whole synovial specimens have been prepared permitting visualization of the vascular bed in a three dimensional plane In 1962 a preliminary report (Kulka et al) based on fifteen cases was published on venular capillary lesions in osteoarthritis and rheumatoid arthritis This has formed the basis for the present study the aim of which has *been to investigate the microvascular derangement in synovial tissues* in osteoarthritis and to make some comparisons with the observations in rheumatoid arthritis

MATERIAL AND METHODS

The synovial tissues obtained for investigation have in most instances been obtained at arthrotomies and in a few cases by needle biopsy The technique used for the latter has been described by Parker Pearson (1963) The distribution of articular sites and pathologic conditions where tissues have been excised is presented in Table 1 As trauma in the hip joint has involved extraarticular femoral neck frac tures and in the knee an arthrotomy for suspected ruptured meniscus the tissues removed at these operations have been regarded as reference cases Microscopic sec tions of these showed no abnormalities.

Table 1 Distribution of disease and articular sites for investigative material

Joint	Trauma	Osteo arthritis	Rheumatoid arthritis	Total
Hip	3	15	5	23
Knee	1	6	19	26
MTP			1	1
Elbow	1		1	2
Wrist			3	3
MCP			1	1
Total	5	21	30	56

MTP = Metatarsophalangeal joint
MCP = Metacarpophalangeal joint

Special care was taken to obtain tissues representative of the disease process. In all instances excepting the hip operations the surgical procedures were carried out in a bloodless field i e a tourniquet was applied to the limb proximal to the field of operation

Immediately on removal the specimens were prepared according to a freeze fixation technique developed by Kulka (1964) The specimen is rapidly but carefully dissected and spread out with its various villi on a piece of filter paper This is put into a container holding a mixture of CO_2 and acetone at a temperature of —70 to —80 C After five minutes it is transferred to tetrahydrofuran at —10 C for fixation and clearing After twenty four hours the specimen is transferred to —4 C for four hours after which it is mounted on a well slide in Canada balsam. The specimen is now translucent and can be studied in three dimensions with a stereomicroscope The advantage of this method is twofold in that it visualizes the capillary venular bed three dimensionally in a life like state and that it permits paraffin sections to be made from the same material

RESULTS

Appearance of Villi

The villi were long and slender with a rather narrow base or short and wide with a broad base Both varieties were seen in all groups with a preponderance of the long and slender villi in the trauma (T) and osteoarthritis (OA) groups (Figure 1), whereas in the rheumatoid arthritis (RA) the overall impression was that villi were plumper and if of a longer variety widened and thickened (Figure 2) One noteworthy difference appeared between the T and OA groups on one hand and the RA group on the other In this latter the distal one third of the villus macroscopically appeared most frequently as a white jellified mass adfixed to the basal two thirds appearing as a cap on this (Fig

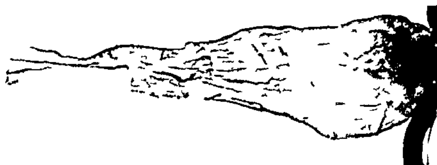


Figure 1 Long slender synovial villus made translucent by freeze fixation technique and clearing (Kulka) From synovial tissue in osteoarthritis knee joint Vascularization is noted to the limit of the tip × 20



Figure 2 Short plump synovial villus from knee joint with rheumatoid arthritis Core of vascularized tissue surrounded by jelly like avascular mass Note sharp border between vascularized and non vascularized tissue Free e fixation and clearing × 20

ure 2) In the three dimensional examination this part appeared completely avascular Signs of previous vascularization remained however in some specimens in that small yellow brownish granules interpreted as hemosiderin were observed Generally the ischemic regions were proximally demarcated by a zone of yellowbrown interstitial pigment which was also interpreted as hemosiderin Occasionally focal capillary extravasation of erythrocytes could be seen in this zone This phenomenon was not encountered in the T group only in the OA group This ischemic appearance on the tip of the villus which is readily seen *in situ* in the opened joint is regarded typical of RA (Figure 3)

Hemorrhage

In evaluating hemorrhage some factors are of importance The time relationship i e whether the signs of hemorrhage are indicative of fresh or old bleeding has to be considered as well as the cause of the bleeding e g whether it may be artifactual a result of the handling of the specimen or of natural occurrence Yellow brownish pigmentation was interpreted as hemosiderin and thus a sign of old hemorrhage Focal extravasation of erythrocytes was regarded as fresh bleeding

In the T group no signs of intravital hemorrhages were observed In some however large blood clots were present which was thought due to the escape of blood from vessels at surgery despite the use of tour



Figure 3 Enlargement of section border zone between vasculari ed and non vascularized area of specimen in Figure 2 Small coiled vessels of venular type are seen bordering the vasculari ed tissue margin Free e fixation and clearing × 100

niquet in two cases In the OA group multiple well outlined focal extravasations of erythrocytes were frequently seen either assembled as small dots in a group or more individually isolated (Figure 4) These extravasations were seen to be equally distributed in areas where capillaries were predominantly present as well as being adjacent to venules Occasionally deposits of hemosiderin were seen and in those instances mostly at the surface In the RA group hemorrhage was as frequent a finding as in the OA group Both focal extravasations of erythrocytes and hemosiderin deposits were seen though the impression remained that old hemorrhage was slightly more common than fresh Irrespective of type of hemorrhage the outline was not always

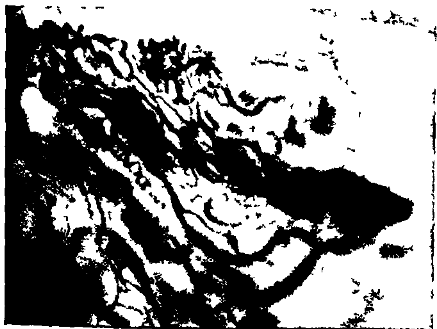


Figure 4 Focal extravasations of varying size of erythrocytes in synovial tissue of osteoarthritis Free e fixation and clearing × 120

as sharp in the OA group and a tendency to diffuseness with indistinct spreading into the tissue was noted Because of this diffuseness the relation of hemorrhage to capillary or venule was not as distinct as in the OA group (Figure 5)

Edema

By the employment of the freeze fixation technique with the following examination of transparent whole mounts edema cannot be visualized An indication of present edema may be obtained by scrutinizing the course of vessels and their individual appearance It has been felt justifiable to ascribe some importance to the visualization of extended taut and string like vessels assuming that the increase in volume by edema may give this appearance to the vessels With this in mind it was found that in the C group no such vessels were present in the OA group only occasionally whereas in the RA group it was a most common phenomenon This stretching of vessels applied to both venules and capillaries alike

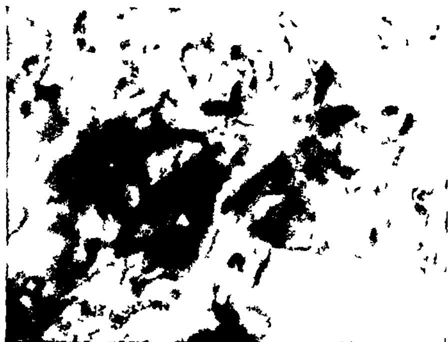


Figure 5 Dark diffuse areas are hemorrhages in synovial tissue of rheumatoid arthritis The venules are dilated and appear atonic Free e fixation and clearing × 120

Arterioles

This method hardly lends itself to a satisfactory study of arterioles and better information is obtained in ordinary histologic sections The reason for this is probably that a combination of surgical handling and freezing causes a vasospasm which may be superimposed on the al ready existing vasospasm particularly engaging the arterioles which may be present as part of disease (Kulka 1959)

Venules

The venular arrangement in the T group appeared quite normal with slender moderately coiled venules forming peripheral hairpin loops (Figure 6) No segmentation was noted nor any indentation The peripheral venules assembled into normal sized collecting veins with normal outline and without any signs of erythrocyte aggregation of pathological significance

In the OA group the venules were in most specimens moderately or more dilated Capillaries emptied directly into dilated venules without



Figure 6. Moderately coiled vessels in hairpin loops and horseshoe shapes in normal synovial tissue. Free e fixation and clearing × 100

any sign of widening just before entering. The venules were moderately coiled but equally often stretched and straight. In the periphery a characteristic sign was a pronounced tortuosity which gave an impression of the vessels being elastic and dynamically active. The tortuosity appeared regionally bound to the periphery of the villi and their arrangement was glomerular like (Figure 7). No segmentation nor indentation was observed. The collecting veins were as a rule widely dilated. A common observation was hypervascularization of the villi. Occasionally congestion of venules was noted. In the RA group the venules were usually dilated. They were straight, taut and congested. They appeared atonic with varying outline and the expression 'venous lake' was used as a working term. Moreover, the venules appeared to be cut off, opening into the tissues without signs of either thrombosis



Figure 7. Glomerular like vascular arrangement in synovial villus in osteoarthritis. Free e fixation and clearing × 60

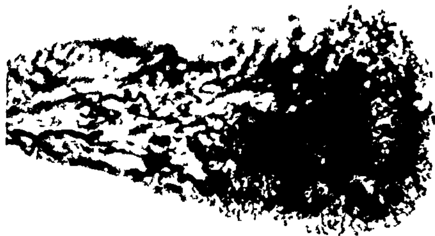


Figure 8 Hypervascularization with irregularly coiled vessels in synovial tissue in rheumatoid arthritis Freeze fixation and clearing × *80*

or hemorrhage They thus looked like tubes with open ends hanging freely without any connections In some venules however a small cloud of extravasated erythrocytes was observed surrounding the open end In occasional specimens moderate tortuosity was encountered In those specimens in which ischemic regions were present a border zone of densely packed venules was observed between vascularized and non vascularized areas Occasionally isolated vascular loops extended into the vascular region Hypervascularization was common No segmentation was noted (Fig 8)

Capillaries

These are difficult to recognize as the endothelial cell layer is not visualized The indication of capillaries however is obtained by the continuous row of red blood corpuscles usually forming a regular pattern In the 1 group no abnormalities were encountered In the OA group the most striking feature was the tortuosity of the capillaries and their glomerular like appearance Occasionally stretching of the capillary network was seen In the RA group the capillaries were often tortuous but more often they were stretched encasing the whole villus in a fish net appearance Many were abruptly cut off without any obvious connection with a venule

Thrombosis

No signs of thrombosis or vascular obliteration were seen in the T or OA groups In the RA group signs of erythrocyte aggregation were present but there was no justification in ascribing to this such pathologic importance as to regard it as thrombosis

COMMENT

The observations in this study tentatively forming a basis for comparison of the microvascular derangement in rheumatoid arthritis and osteoarthritis have not in any way served as material to attempt a postulation on the origin of the individual disease entities

The reactivity of the vascular bed in the target organ i e synovial tissue has attracted the greatest interest as it is becoming more and more evident that the response of the vasculature in connective tissues is very much the same irrespective of stimulus Differences do of course exist as for example in many heavily localized infections where despite great cellular activity with tissue damage the vessels remain on the whole completely intact Many conditions however of various origin evoke a vascular reaction in connective tissues which generally appears rather uniform It seems that in many instances it is more a question of degree or grade of involvement and reaction—in which the time relationship between onset of disease and synovial manifestation stands out as most important—than the type and form of response

In earlier studies by Kulka (1955 1959 1961 1964) evidence has been presented that in two such different conditions as rheumatoid arthritis and cold injury the vascular response in connective tissue is mainly the same Thus corresponding changes have been found in the two conditions including excessive venous and venular dilatation with persistence of segmented arteriolar spasm segmental venular leakage of plasma progressive venular and capillary erythrostasis and arteriolar venular shunting with bypassing of the static capillary venular plexi

As mentioned in the introduction this type of microvascular dysfunction appears in many human pathologic conditions In few instances e g tuberculosis and syphilis pure pathognomonic features are encountered which may explain part of the vascular reaction and it thus appears that the response is of the non specific inflammatory typ Considering this it may therefore not be so surprising to find a

number of similar features in the target organs of two such differing diseases as rheumatoid arthritis and osteoarthritis On perusing the results in this investigation the impression remains that a number of features resemble each other though there exists a difference in intensity and distribution principally with a preponderance in the synovial tissues of rheumatoid arthritis

The findings in both osteoarthritis and rheumatoid arthritis have supported the experimental evidence that inflammatory tissue damage results from gradual stagnation of the circulation through venular and capillary plexi with temporary persistence of blood flow in preferential arteriolar venular channels This progressive microcirculatory failure may be initiated by disproportionate dilatation of the venous drainage bed with a corresponding decrease in linear flow velocity The *associated increase in viscous resistance to blood flow is augmented by* plasma leakage from the dilated vessels leading to progressive hemoconcentration and further slowing of flow The effects on blood viscosity of dysproteinemia and erythrocyte aggregation may be related to the intensity of this non specific pathogenetic process in rheumatoid arthritis and related diseases

SUMMARY

A study has been made with tentative comparison of the vascular lesions in synovial tissues from cases of rheumatoid arthritis and of osteoarthritis The material consisted of fifty six joints of which thirty were rheumatoid and twenty one had osteoarthritis Five had been subjected to trauma No abnormalities were observed in these

A new freeze fixation technique developed and introduced by Kulka (1964) was used This method permits visualization of the capillary venular bed in a three dimensional plane in a life like state The specimen prepared in this way can also be used for paraffin sections

The results yielded no abnormalities in the *trauma* group

In the *osteoarthritis* group there were moderate edema multiple erythrocyte extravasations limited to capillaries and venules some hemosiderin deposition dilated venules and capillaries with some tortuosity and no thrombosis

In the *rheumatoid arthritis* group principally the same findings were made though the intensity and distribution of pathologic features were more prevalent Additional findings in this group were an atonic condition of the venules and widespread regions of vascular obliteration

The reactivity of the vascular bed in connective tissues to various stimuli in a rather uniform way is briefly discussed There is accumulating experimental evidence that inflammatory tissue damage results from gradual stagnation of the circulation through venular and capillary plexi with temporary persistence of blood flow in preferential arteriolar venular channels

The observations on microvascular derangement in both the rheumatoid arthritis and osteoarthritis groups conform with the vascular findings in experimentally induced inflammatory damage

The observations in this investigation support the assumption that the difference in the vascular derangement in synovial tissues in osteoarthritis and rheumatoid arthritis is principally more a question of degree intensity and distribution than type and form

ACKNOWLEDGEMENT

The cooperation of *J P Kulka* is gratefully acknowledged

REFERENCES

Brånemark, P I Lindstrom, J Jonsson Laine V & Vainino K (1963) Capillary structure and function in rheumatoid arthritis *Acta rheum scand* 9 284–292

Cruickshank, B (1954) Arteritis of rheumatoid arthritis. *Ann rheum Dis* 13 136

Elmore S M., Malmgren R. A & Sokoloff L (1963) Sclerosis of synovial blood vessels *J Bone Jt Surg* 45 A 318.

Grueter H & Rutt A (1962) On the morphology of hip joint diseases developing into coxarthrosis *Z Orthop* 95 401–439

Hollander J L. (1966) *Arthritis and allied conditions* p 190 Lea & Febiger Philadelphia

Kulka J P (1959) The pathogenesis of rheumatoid arthritis *J chron Dis* 10 588 402

Kulka, J P (1961) Vasomotor microcirculatory insufficiency Observations on non freezing cold injury of the mouse ear *Angiology* 12 491

Kulka J P (1964) Microcirculatory impairment as a factor in inflammatory tissue damage *Ann N Y Acad Sci* 116 1018

Kulka J P (1966) Vascular derangement in rheumatoid arthritis In Hill A (ed) *Modern trends in rheumatology* pp 49–69 Butterworths London.

Kulka J P., Bocking D Ropes M & Bauer W (1955) Early joint lesions of rheumatoid arthritis. *Arch Path* 59 129–150

Kulka, J P Holdsworth D E & Potter T A (1962) Venular-capillary lesions of osteoarthritis and rheumatoid arthritis Stereo microscopic observations on frozen fixed synovial biopsies *Arthr and Rheum.* 5 305

Parker R. & Pearson C. (1963) A simplified synovial biopsy needle. *Arthr and Rheum* 6 172

Sokoloff L. McCluskey R T & Bunim J J (1953) Vascularity of early subcutaneous nodule of rheumatoid arthritis *Arch Path* 55 475

Sokoloff L. (1963) The pathophysiology of peripheral blood vessels in collagen diseases In *The peripheral blood vessels* Williams & Wilkins Baltimore

Acta orthop Scandinav 40 765–772 1970

Department of Pathology II (Head Sture Falkmer) University of Umeå
Umeå Sweden

THE HUMAN INTERVERTEBRAL DISC

A Micro Angiographical Study on Its Vascular Supply at Various Ages

Ove Hassler

Received ix 68

It is well known that degeneration of the human intervertebral disc is an important cause of disability The mechanism of the degeneration is obscure but it starts relatively early in life The degenerative process in the discs has been thoroughly studied by various biophysical biochemical and morphological methods (Friberg & Hirsch 1950 Hirsch & Schajowicz 1952 Hirsch Paulson Sylven & Snellman 1952 Nachemson 1960 Hooff 1964 Mineiro 1965 Galante 1967)

It is a generally accepted fact that the intervertebral discs in adults (even in young adults) normally do not contain vessels (Amato & Bombelli 1959 Mineiro 1965) The vessels at the margins of the disc do not seem to have been very much studied and particularly not by micro angiography Because the status of these vessels was assumed possibly to be of some importance for the degenerative process it was considered desirable to study them specially Spondylosis with degeneration of the discs intraspongy nuclear herniations disc calcifications and posterior protrusions of the nucleus pulposus were observed in the angiograms and were related to the angiographical findings

MATERIAL AND METHODS

The material was obtained in the Department of Pathology University Hospital Umeå It was taken within 24 hours *post mortem*. The dead bodies were kept at room temperature for the first few hours after death and then at +2 to +6 C. The material comprised nine stillborn babies weighing 510–4200 g nine children aged 1 month 2 months, 7 months 1 3 5 9 12 and 13 years, and 10 adults aged 27 39 42 56 64 69 71 8. 9 and 82 years The clinical records contained infor

Supported by grant No B69 12X 561 05 from the Swedish Medical Research Council.

mation on low back disorder only in one case (that of the 78-year old man who had a spondylosis diagnosed by X rays)

Cannulas as large as possible were introduced into both common iliac arteries The aortic arch below the departure of the left subclavian artery and all large branches from the aorta to parenchymatous organs were tied off Fine grained X ray contrast medium (a 7 % aqueous suspension of Micropaque® Damancy Ltd England) was injected for half an hour through the cannulas at a pressure of 0 mm Hg in the stillborn babies 100 mm Hg in the children and 160 mm Hg in the adults Two blocks of the vertebral column (one comprising vertebrae C5 D1 and the other comprising L3 S1) were removed and fixed in formalin The specimens from the adults were first examined with a clinical diagnostic X ray machine (60 kV 8 mAs FSD 100 cm Singul X non screen film from CLA verken Strangnäs, Sweden) The discs with calcifications visible on the radiograms were then excised divided into 2 mm thick slices and examined by micro radiography (Hassler 1964) on Kodak Maximum Resolution Plates Then the remaining parts of all columns were decalcified in Perenyi's solution (Silverton & Anderson 1961) and divided in the sagittal plane into slices which were 2-4 mm thick and examined by micro radiography on Kodak Maximum Resolution Plates as above The discs were also graded with regard to the macroscopic changes (Friberg & Hirsch 1950 Hirsch & Schajowicz 1952) All intervertebral disc calcifications all slight posterior protrusions of the nucleus pulposus all intraspongy nuclear herniations, and all vascular ingrowths in severely degenerated discs were embedded in paraffin and sectioned serially together with the adjacent disc and vertebral tissue Furthermore 20 discs taken at random from the subjects aged 56 years or more were sectioned serially The histological sections were stained with van Gieson's method, haematoxylin eosin PAS or alcian blue

RESULTS

The filling of the vessels with X ray contrast medium was practically complete in about 60 per cent of the cases In the remaining cases the filling was incomplete to varying extents, but this was not a disadvantage in all respects Various areas of arterial blood supply could then be more easily delineated (the capillaries supplied by one artery were not filled with contrast medium while the capillary area of another artery was filled) and arteriovenous anastomoses were easier to study

Figure 1 Micro angiograms of 2 mm thick sagittal slices from the disc between vertebrae L4 and L5 A Stillborn baby weighing 1370 g The vertebral margins have a dense net of capillaries and several vessels penetrating far into the disc occur Also parts of the adjoining discs are seen in the picture × 16 B Five year old boy The disc is upwards The vertebral margins are still rather densely vascularised and solitary penetrating vessels can also be seen × 11 C Fifty six year old man Only a few vessels occur at the vertebral margins and none is penetrating × 11

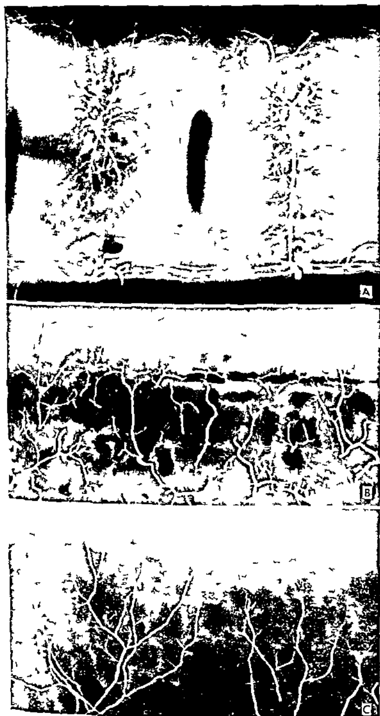


Figure 1



Figure 2 a and b Micro angiograms from sagittal 2 mm thick slices through the anterior free border of the disc between L4 and L5 The free margins of the discs were practically equally richly vasculari ed in the three year old girl (a) an l the 69 year old woman (b) in c ntrast to the vertebral margins that appear in the right upj er and lower corners × 9 C Micro angiogram from a sagittal 9 mm thick slice through the posterior part of the dis between L4 and L5 in a 97 year-ol l man A slight disc protrusion mainly of the nucleus pulj osus i ecurs × 19

Figure 3 a Intraspongy nuclear herniation in a 64 year old man The vascul iture of the vertebral margins sh u s n > special features The dis is upwards × 9 B Inter vertebral disc calcifications situate l near the margins of the disc that were ordi narily vas uları ed (but were examined separately because they ha l to be decal cified before examinati on) × 9 C Irregular vascular ingrowth in the non specific granulation tissue of a sei erely degenerated dis (gr i le 4) The dis is to the right The vertebral margin is arrowe l × 12

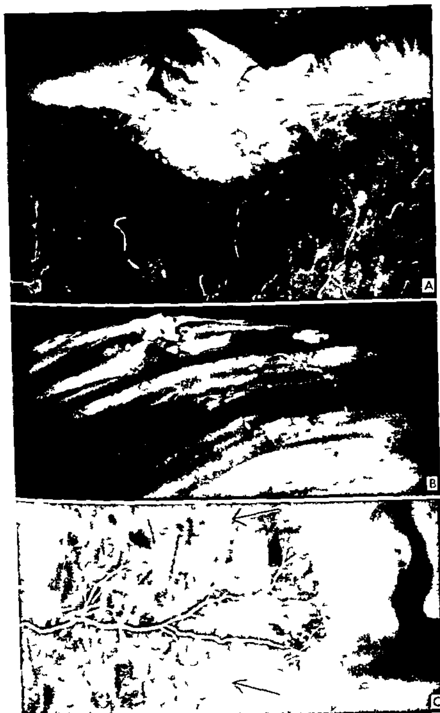


Figure 3

The intervertebral discs of the stillborn babies and the children had a much more ample vascular supply than those of the adults. At the vertebral margins the capillary network was denser in the babies and children than in the adults (Figure 1). Several vessels penetrating deeply into the discs occurred in every disc with good X-ray contrast filling examined in the babies. In the children the penetrating vessels were relatively smaller and less numerous with increasing age. In the 13 year old boy and in all the adults no such vessels were observed. The penetrating vessels were observed somewhat more often in the lumbosacral discs than in the cervicothoracal discs. In contrast to the vertebral margins the free margins of the discs were almost equally richly vascularized in the children and the adults (Figure 2). No sex differences were noted. When the histological serial sections were correlated to the micro-angiograms, it was seen that histological age changes as PAS-reactive granular substance and alcian blue positive material (Hoof 1964) were regularly situated far from the ordinary vessels. The ordinary vascular pattern at the vertebral margins was exceptionally sparse in the neighbourhood of the histological age changes. However, when the latter got more marked with hole and cleft formation of the disc and with ingrowth of granulation tissue, secondary ingrowth of irregular vessels also occurred (Figure 3c).

In the 27 year-old man a slight protrusion of the nucleus pulposus was noted (Figure 2c) in some discs. Some vessels seemed to have been blocked, but otherwise the angio-architecture was not changed.

In all the subjects aged 56 years or more spondylosis of varying degree was seen. The vertebral margin of vessels was then uneven, which was difficult to demonstrate on printed angiograms because of the few vessels. When the discs were graded according to the degree of degeneration, the discs of grades 1–2 showed no special vascular changes, whereas the discs of grades 3–4 showed uneven vertebral margins of vessels (like the cases of spondylosis, most of the discs in which were classed as grade 3 or 4). As a rule much granulation tissue and sequestrae with numerous irregular vascular ingrowths occurred in grade 4 (Figure 3c). These vascular ingrowths were especially marked in the unco-vertebral region, confirming the observations made by Hirsch & Schajowicz (1952, 1967).

In the subjects aged 56 or more a total of five intraspongy nuclear herniations and 18 disc calcifications were observed. No special features in the vasculature (Fig. 3) at the border of the herniations or near the

calcifications could be found The calcifications occurred as a rule near the margins of the discs and thus near to vessels

COMMENTS

It is obvious that the blood supply of the intervertebral disc is impaired markedly with increasing age because its penetrating vessels disappear and the capillaries at the vertebral margins (which are larger than the free margins) become more sparse The adult discs are thicker than those of the children especially in the lumbar region Probably the discs also become less easily diffusible with increasing age Therefore it may be expected that the nutrition of the disc will be deficient in adults which may be a contributory cause of the common degenerative changes The presumed situation with bad nutrition probably already occurs in the young adult which may partly explain why the degenerative changes and disc protrusions develop comparatively early in life Evidence for a connection between histological age changes and impaired vascularization was also obtained

One reason why the intervertebral discs of the children are much more vascularized than those of the adults is of course also that the former are growing while the latter are in a more static state

Severe disc degeneration was associated with secondary vascular ingrowth that was sometimes marked This secondary ingrowth occurred in granulation tissue and resembled that described in detail in the cervical spine (Hirsch Schajowicz & Galante 1967)

SUMMARY

A micro angiographic study was performed on the vascular supply of the human intervertebral disc at different ages In the children the vertebral margins of the discs were much more richly vascularized than in the adults Regular vessels penetrating into the disc were found frequently in stillborn babies sparsely in children aged 1 month to 12 years and not at all in adults The angio architecture in the neighbourhood of intraspongy nuclear herniations and intervertebral disc calcifications was normal Irregular vascular ingrowths in granulation tissue in the disc occurred in cases of severe disc degeneration

REFERENCES

Amato V P & Bombelli R (1959) The normal vascular supply of the vertebral column in the growing rabbit *J Bone Jt Surg* 41 B 782–795

Friberg S & Hirsch C (1950) Anatomical and clinical studies on lumbar disc degeneration *Acta orthopaed Scand* 19 222

Galante J O (1967) Tensile properties of the human lumbar annulus fibrosus *Acta orthop scand* Suppl 100 1–91

Hassler O (1964) Angio architecture in hydrocephalus An autopsy and experimental study with the aid of micro angiography *Acta neuropath* 4 65–74

Hirsch C Paulson S Sylven B & Snellman O (1952) Biophysical and physiological investigations on cartilage and other mesenchymal tissues VI Characteristics of human nuclei pulposi during aging *Acta orthop scand* ** 175–183

Hirsch C & Schajowicz F (1952) Studies on structural changes in the lumbar annulus fibrosus *Acta orthop scand* 22 184

Hirsch C Schajowicz F & Galante J (1967) Structural changes in the cervical spine—A study on autopsy specimens in different age groups *Acta orthop scand* Suppl 109 1–77

Hooff van den A (1964) Histological age changes in the anulus fibrosus of the human intervertebral disk—With a discussion of the problem of disk herniation *Gerontologia* 9 136–149

Mineiro J D (1965) *Coluna vertebral humana alguns aspectos da sua estrutura e vascularizaçao* Lisboa

Nachemson A (1960) Lumbar intradiscal pressure—Experimental studies on post mortem material *Acta orthop scand* Suppl 43 1–104

Silverton R E & Anderson M J (1961) *Handbook of medical laboratory formulae* pp 265–266 Butterworths London

Acta orthop. Scandinav. 40, 773–776, 1970

Department of Orthopaedics, University Hospital, Lund, Sweden
(Head: G. Wiberg, M.D.)

LONG-TERM RESULTS OF LAMINECTOMY IN SPONDYLOLISTHESIS

CARL AXEL CEDELL & GUNNAR WIBERG

Received 25.ix.68

Since Gill, Manning & White (1955) reported on their favourable results of laminectomy in spondylolisthesis, this operation has been used by many surgeons in different parts of the world. Though nobody has succeeded in reproducing the excellent results of treatment of Gill et al., this surgical method has, however, more or less been placed among the orthopaedic standard operations. Good results in selected cases have been reported by Woolsey (1954), Raynal, Thys & Delcourt (1962) and others.

In 1961 Cedell in this journal gave an account of a patient material which in 1955–1959 at the Department of Orthopaedics, University Hospital, Lund, was operated on by laminectomy according to Gill. The results were so encouraging that the method has continued to be used in the clinic. During the years 1960–1966 a laminectomy was performed on another 16 patients, 11 men and 5 women, their ages ranging from 28 to 72; 8 patients were below 50. In 1967 the patients were followed up by a questionnaire, to which 14 of the 16 patients contributed. The observation time was 1 to 2 years in 4 patients and 3 to 7 years in the remaining 10 patients. Six of the patients had an observation time of 5 years or more. The result of the operation in regard to the back pain was the following: 10 patients (7 men and 3 women) had improved, 1 female patient had the same symptoms as before the operation, and 3 patients (2 men and 1 women) gradually felt worse (see Table 1). No patient was completely symptom free. The ages of those patients who stated a gradual deterioration were 47, 53 and 66 at the operation. Five of those patients who stated an improvement also wore a corset at work after the operation. Five patients (4 men and 1 woman) had no sciatic pain, and 9 patients (5 men and 4 women) had remaining slight neurological symptoms. Two patients have later been operated on with

Table 1 Results of laminectomy in 14 patients operated on in 1960 1966 Observation time of 1–7 years

Group	Men	Women	Total	%
Improved	7	3	10	71 4
Unchanged	–	1	1	7 2
Worse	2	1	3	21 4
Total	9	5	14	100 0

Table 2 Results of laminectomy in 20 patients operated on in 1955–1959 Observation time of 8–11 years

Group	Men	Women	Total	%
Improved	10	3	13	65 0
Unchanged	1	–	1	5 0
Worse	3	3	6	30 0
Total	14	6	20	100 0

fusion a middle aged man who had experienced a deterioration after the laminectomy and a 29 year old woman to whom the operation had given certain but not sufficiently good relief of the symptoms

At the same time a questionnaire was sent to the 21 patients included in Cedell s material from 1955 to 1959 20 responded 14 men and 6 women One woman had died during the observation time she belonged to the category of patients stated to have a distinct improvement after the laminectomy The observation time now came to cover 8 to 11 years 13 patients (10 men and 3 women) felt better 1 male patient had unchanged symptoms and 6 patients (3 men and 3 women) felt worse than before the operation (see Table 2) None of the patients was now completely symptom free Only 6 patients wore a corset 4 of them belonging to the group worse

If among the 20 patients a comparison was made between the result of the laminectomy as it appeared at the follow up examination in 1960 and at the examination by a questionnaire in 1967 the following was found 3 patients stated that they had improved all of whom in 1960 were classified as "unchanged 6 patients reported unchanged symptoms 5 of whom in 1960 registered as "improved and 1 as "worse 11 patients had become worse 9 of them had changed from "symptom free" to "improved 1 from "improved to "unchanged 1 from "improved"

Table 3 Comparison of the results of laminectomy in 1960 and 1967 in 20 patients operated on in 1955–1959

Group	1960			1967		
	Men	Women	%	Men	Women	%
Improved	10	2	60 0	10	3	65 0
Unchanged	3	4	35 0	1	–	5 0
Worse	1	–	5 0	3	3	30 0
Total	14	6	100 0	14	6	100 0

to worse and 4 patients from unchanged to worse The ages of the patients included in the group worse varied between 39 and 58 at the operation During the 7 years further observation time a certain degree of deterioration of the results had taken place so that the number of those patients who reported increased back pain after the operation had risen from 5 to 30 per cent 65 per cent of the patients or 5 per cent more than earlier on the other hand reported an improvement by the operation The 7 patients in 1960 stating unchanged symptoms after the operation had 7 years later in 3 cases improved and in 4 cases become worse in comparison with their preoperative symptoms (see Table 3) It may be added that 8 patients (7 men and 1 woman) in the questionnaire stated slight sciatic pain which broadly speaking agrees with the findings in 1960

In summary the examination has shown that the laminectomy in about two thirds of the cases has led to a distinct and protracted improvement as regards the back pain of the patients The method must therefore be considered advisable before an operative fusion is resorted to Laminectomy is accompanied by a short hospital and immobilization time and is no impediment to a future operative fusion if necessary as the loose arch of the olisthetic vertebra at the latter operation should be removed anyhow In all probability the loose arch has no stabilizing function for which reason it seems unlikely that the laminectomy *per se* might provoke an increasing olisthesis

SUMMARY

In 1955–1959 24 patients with spondylolisthesis were operated on with laminectomy *ad modum* Gill at the Department of Orthopaedics University Hospital Lund Twenty-one patients were re examined in 1960

at which a marked reduction of the back pain was found in at least two-thirds of the cases. In 1960–1966 another 16 patients were operated on with laminectomy and were re-examined by a questionnaire in 1967. These results were equally good. None of the patients was completely symptom free, but 70 per cent stated a distinct improvement. At the same time the patients included in Cedell's material from 1956 to 1959 were also followed up by a questionnaire, whereby the length of the observation time in all came to cover 8 to 11 years. The result registered at the follow-up examination in 1960, i.e. an improvement in about two-thirds of the cases, has on the whole remained unchanged, for which reason we consider laminectomy to be a method well worth trying before an operative fusion is resorted to.

REFERENCES

Cedell, C. A. (1961): On the effect of laminectomy on back pain in spondylolisthesis. *Acta orthop. scand.* 31, 130.

Gill, G. G., Manning, J. G. & White, H. L. (1955): Surgical treatment of spondylolisthesis without spine fusion. *J. Bone Jt Surg.* 37-A, 493.

Raynal, L., Thys, R. & Delcourt, I. (1962): Considérations sur l'opération de Gill. *Acta orthop. belg.* 28, 127.

Woolsey, R. D. (1954): Mechanism of neurological symptoms and signs in spondylolisthesis at fifth lumbar and first sacral level. *J. Neurosurg.* 11, 67.

Acta orthop Scandinav 40 777–787 1970

Sophies Minde Orthopedic Hospital (Head Ivar Alvik) Oslo

GLENOIDPLASTY AS A TREATMENT FOR RECURRENT ANTERIOR DISLOCATION OF THE SHOULDER

GALAL Z SAID & INGULF MIDBØ

Received ix 68

Many operations have been devised for the treatment of recurrent anterior dislocation of the shoulder each based upon conceptions of the pathological changes occurring in the shoulder joint

Bankart (1923 1938) believed that the essential and the sole lesion in recurrent dislocation of the shoulder is the detachment of the labrum glenoidale from the anterior edge of the glenoid The labrum glenoidale was considered at that time to be a fibrocartilaginous structure' which has poor if any healing potential According to Bankart labrial detachment therefore produces a permanent laxity and weakness of the anterior part of the shoulder joint However it has been shown by Mosely & Overgaard (1962) from an extensive embryological and anatomical study that the labrum is mainly fibrous and contains no cartilage They describe in certain cases an anomalous attachment or insufficient development of the middle glenohumeral ligament as the basis for recurrence

Each time the shoulder dislocates the posterior part of the humeral head is impacted against the anterior lip of the glenoid resulting in the well known posterolateral defect in the humeral head but the impact will also damage the glenoid rim by rounding it off or fracturing it. Though this rounding off and depression of the anterior glenoid rim was recognized many workers (Bost & Inman 1942 Adams 1948 Jacobsson 1950) little attention has yet been paid to it in the treatment of recurrent dislocation of the shoulder

In the Eden Hybinette operation a bone graft is placed against the anterior aspect of the neck of the scapula and rim of the glenoid in such a way that it acts as a bone block to the anterior displacement of the humeral head (Palmer & Widen 1948) The graft is tucked under the remains of the labrum and periosteum without any additional fixation In 1948 Eyre Brook suggested fixing an iliac bone graft to the neck of the scapula by means of a screw for cases showing a groove in the head of the humerus

Alvik (1951) modified the original Eden Hybinette technique so as to reconstruct the anterior lip of the glenoid by means of a well fixed graft and thus to secure support for the humeral head This operation was first performed in 1948 and since that time it has been the only operative procedure for recurrent dislocation of the shoulder at Sophies Minde Orthopedic Hospital in Oslo Norway It is the aim of this study to evaluate this operation

OPERATIVE TECHNIQUE

With the patient in the supine position the shoulder joint is approached through the usual anterior approach Separation of the fibers of the deltoid muscle about one cm lateral to the deltopectoral groove avoids the cephalic vein and provides direct access to the shoulder joint The biceps and the coracobrachialis muscles are retracted medially The subscapularis tendon and the capsules are cut vertically about one cm from the insertion of the muscle The joint is inspected and any damage to the capsule or labrum is noted and assessed

A thin osteotome is used to make a trench about 20 mm long 2 mm broad and 15 mm deep running in a medial and backward direction in the front of the neck of the scapula as close to the edge of the glenoid as possible The iliac bone is exposed and a wedge of bone 25 mm long 20 mm broad and 5 mm thick at its base is cut from its outer cortex The graft is then jammed into the trench with its cortical surface fac

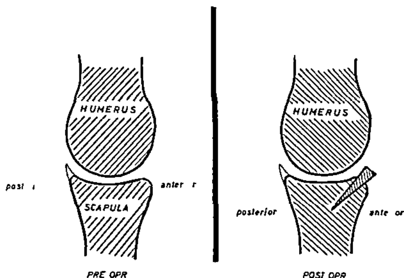


Figure 1 Preoperative Absence of the glenoid labrum anteriorly and rounding off and depression f the anterior part of the glenoid Postoperative Alvik s mo lifi cation of the Eden Hybinette operation for recurrent dislocation of the shoulder

ing laterally in such a way that about 0 5–1 cm of it projects forwards and laterally deepening the glenoid cavity (Figures 1 and 5) No at tempt is made to reattach the detached labrum to the glenoid rim The subscapularis tendon and the capsule are sutured back with some over lapping and the wound is closed

POSTOPERATIVE CARE

The arm is supported on an abduction splint for 6 weeks After a few days arm raising exercises are encouraged When the splint is dis carded gentle active exercises are instituted to restore movement and power

MATERIAL

Twenty three successive cases of recurrent anterior dislocation of the shoulder were treated by this operation in the period 1948 1966

Eighteen patients were examined by the authors and three others answered a questionnaire Two of the latter three were examined radiologically in the local hospital and the films ent to us T o patients were lost to follow up

EXAMINATION

These patients were examined clinically and radiologically. External rotation was assessed with the arm lying beside the body (position I) and also with the hands behind the head (Dickson & Devas 1957) a position which combines external rotation and abduction (position II). These positions were photographed and the range of external rotation was measured on the photographs. In this study we used to measure the degree of loss of external rotation as compared to the other side rather than recording it as a definite figure because of the individual variation. This method of comparison however could not be applied to one of our patients (case 4) because he had been operated upon on the other side also by another technique and had a marked limitation of external rotation on that side (Figure 2).

Radiological examination included an antero posterior view in the neutral position, an antero posterior view in 60–70 degrees internal rotation and an axial view with the shoulder joint in abduction, external rotation and hyperextention to show whether there was a tendency of the joint to subluxate.

RESULTS

No pain or weakness was found in the operated shoulders in any of the 18 patients examined by us or the 3 who answered the questionnaire. Recurrence has not taken place in any of these patients.

The range of movement was determined in the 18 patients available for examination. The findings of limitation of external rotation post operatively are given in Table I.

Table I Limitation of external rotation in 17 patients

Position	<10	>20	10–20	Maximum	Average
I	7	7	3	23	12
II	9	6	2	4	11

It is worth noting that sometimes there was a great discrepancy in the degree of limitation of external rotation as measured in positions I and II (Table I and Figure 2). Abduction elevation of the arm was normal in all patients except 2 in whom there was a limitation of 10 and 13 degrees respectively (cases 19 and 21). All other movements were normal.

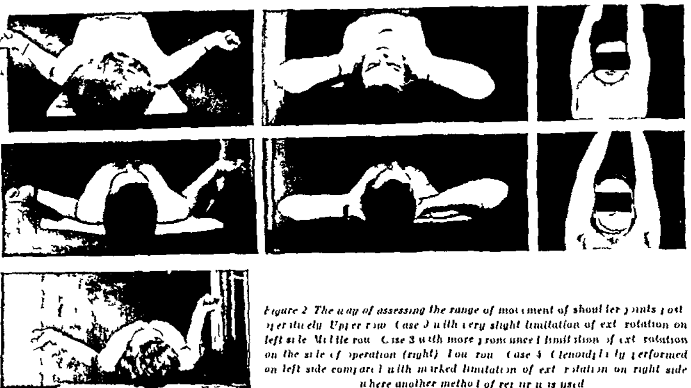


Figure 2 The way of assessing the range of movement of shoulder joints post operatively Upper row Case 2 with very slight limitation of ext rotation on left side Middle row Case 3 with more pronounced limitation of ext rotation on the side of operation (right) Lower row Case 4 Glenoidplasty performed on left side compared with marked limitation of ext rotation on right side where another method of repair was used

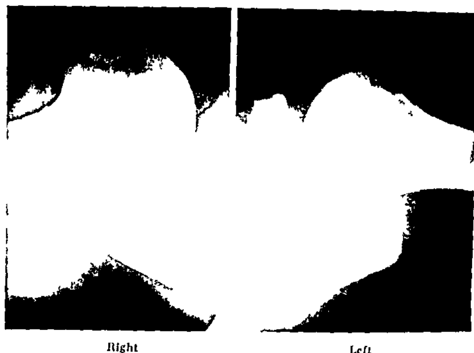


Figure 3 A Right and left shoulder joints preoperatively showing the subluxation on right side

All the patients were satisfied with their shoulders and were able to do everything they wanted with that upper extremity

PREOPERATIVE RADIOGRAPHIC FINDINGS

A postero lateral defect in the humeral head was present in 10 out of 21 patients as shown in internal rotation radiographs What we call a defect is a notched out area having a sharp border parallel with the shaft of the humerus

Axial views were available for 17 patients Eleven of these showed a varying degree of forward subluxation of the head of the humerus (Figure 3) amounting in some to two thirds of the glenoid The anterior glenoid rim was found to be rounded off and sclerotic or defective in 14 patients One of these showed an obvious fracture of the anterior glenoid margin (Figure 4) and three showed evidence of periostial stripping in the form of subperiostial bone formation

Evidence of osteoarthritic changes was present in only one patient who had had her shoulder operated upon 7 years previously by another technique (case 13)



Figure 3 B Right shoulder 3.5 years postoperatively showing well formed glenoid fossa preventing subluxation (Case 5)

OPERATIVE FINDINGS

The labrum glenoidale was found to be either loose or missing in all patients except one (case 8) In some cases it was frayed out and represented only by a thin strand attached to the glenoid rim at one end

The anterior margin of the glenoid was found to be rounded off and depressed in its lower part in 16 cases In 3 others it was considered to be normal and in the remaining 4 cases no mention of the glenoid rim was made The articular cartilage in case 13 was stated to be degenerated

POSTOPERATIVE RADIOGRAPHIC FINDINGS

In all patients except one (case 4) the graft was found to form a smooth continuation of the glenoid in an antero-inferior direction

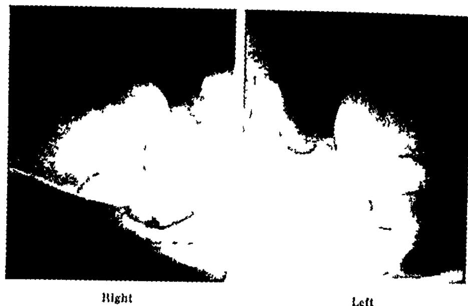


Figure 4 Right and left shoulder showing obvious fracture of the anterior edge of left glenoid fossa (Case 9)

front of the humeral head (Figure 5) In the exceptional case the graft was almost completely absorbed (bone bank graft)

Two patients showed a slight tendency to subluxation, however much less than that seen in the preoperative radiographs

Three patients showed lipping at the inferior border of the humeral head without any other symptoms of osteoarthritis (Figure 6)

DISCUSSION

This operation aims to reconstruct the anterior glenoid rim and to increase the surface area of the glenoid fossa It might rightly be called a glenoidplasty The reconstructed glenoid provides a rigid anterior support for the humeral head however lax and damaged the anterior soft tissues might be No attempt is made to suture the loose labrum or capsule to the glenoid rim Even if there is a big defect in the back of the head of the humerus it cannot engage onto the anterior glenoid rim therefore there is no need to limit external rotation as advised by Watson Jones (1948)

That these shoulders were stable after the operation is proved by two factors None of the patients had a recurrence of their dislocations and the tendency of the joints to subluxate as shown radiographically in

Pre operative





Post operative

Figure 5 Left shoulder before operation and 2.5 years after with excellent build up of lower anterior edge of glenoid fossa (Case 10)



Figure 6 Solid build up of glenoid fossa 7 years after operation with some lipping of humeral head without other symptoms of osteoarthritis (Case 1)*

axial views was present in only 2 patients after operation as opposed to 11 before

The average limitation of external rotation in this series is 12 degrees as determined with the arm lying beside the body and 11 degrees as determined with the hands behind the head This is much less than that reported by most workers because limitation of external rotation is not a principle in this technique

Radiological examination showed lipping at the inferior margin of the humeral head in 3 patients This lipping was absolutely asymptomatic It is not possible to compare this with possible degenerative changes produced by other operative methods as almost no records have been published of subsequent postoperative radiographic investigation of the operated joints We wonder whether the unphysiological limitation of external rotation as produced by the Putti Platt and Bankart operations or the insertion of a bone graft which abuts onto the anterior lip of the glenoid as in the original Eden Hybinette operation does not subsequently lead to degenerative changes which may be seen radiographically in these joints

SUMMARY

Initially this paper gives a review of different opinions as to the etio logy of recurrent dislocation of the shoulder joint Different methods used for repair of the defect are mentioned

The authors hold the opinion that a defect or real fracture of the anterior border of the glenoid fossa is the most likely reason for re peated dislocations

An operative method Alvik s modification of the Eden Hybinette operation is described

Follow up of 21 patients treated by this method showed that no patients have had recurrence and that the loss in range of motion is of no functional importance The follow up examination was performed 1–19 years (average 6 years) after operation

REFERENCES

Adams J C. (1948) Recurrent dislocation of the shoulder *J Bone Jt Surg* 30 B 26

Alvik, I (1951) Tre tilfelle av habituelle skulderleddsluksasjon operert a. m. Hybinette. *Nord med T* 45 96

Bankart A S B (1923) Recurrent or habitual dislocation of the shoulder joint. *Brit med J* 2 1132

Bost F C. & Inman V T (1942) The pathological changes in recurrent dislocation of the shoulder a report of Bankart s operative procedure *J Bone Jt Surg* 24-A 595

Dickson J W & Devas M B (1957) Bankart s operation for recurrent dislocation of the shoulder *J Bone Jt Surg* 39 B 114

Eyre Brook A L (1948) Recurrent dislocation of the shoulder *J Bone Jt Surg* 30 B 39

Jacobsen A (1950) Radiography of the anterior glenoid rim in recurrent dislocation of the shoulder joint. *Acta orthop scand* 20 1

Moseley H F & Øvergaard B (1962) The anterior capsular mechanism in recurrent anterior dislocation of the shoulder *J Bone Jt Surg* 44-B 913

Palmer I & Widén A (1948) The bone block method for recurrent dislocation of the shoulder joint *J Bone Jt Surg* 30 B 53

Watson-Jones R (1948) Note on recurrent dislocation of the shoulder joint. *J Bone Jt Surg* 30 B 49

Acta orthop Scandinav 40 788-796 1970

Coast Hospital (Former head H Storen) Stavern Norway

OPERATIVE ELEVATION OF THE MEDIAL TIBIAL JOINT SURFACE IN BLOUNT'S DISEASE

One Case Observed for 18 Years After Operation

H Storen

Received xi.68

From follow up studies of 71 cases with Blount s disease Langenskiold (1964) concluded that tibio fibular osteotomy provides a favourable outlook when performed before the age of eight years Later osteo tomies are of less benefit and often have to be repeated In addition at the age of twelve the operation must be supplemented with epiphy siodesis of the lateral tibial condyle and fibular head

However in some cases with extreme sloping osteotomy will not suffice The lack of support for the medial femoral condyle and the ensuing laxity of the lateral ligaments result in a varus position, which will be aggravated on weight bearing (Figure 2)

The logical treatment would be to elevate the sloping medial tibial joint surface to its normal level The first report of an operation of this sort appears to be given by Langenskiold (1961) who reported good results after five years follow up in his three cases

The scarcity of reports on this useful operation is believed to warrant a report on one case which I operated by the elevation technique in 1951 and have followed up for 18 years

CASE REPORT

M G female born 16 July 1938 The patient was first examined at five years of age because of pains in the right knee which showed a slight varus X ray revealed beginning Blount s disease She failed to return for control until she was eight, when she had developed a marked genu varum

23 July 1946 she had a tibio fibular osteotomy with overcorrection in valgus However the varus deformity gradually recurred and four years after the first operation on 16 April 1950 a second tibio fibular osteotomy was performed with overcorrection to ten degrees valgus

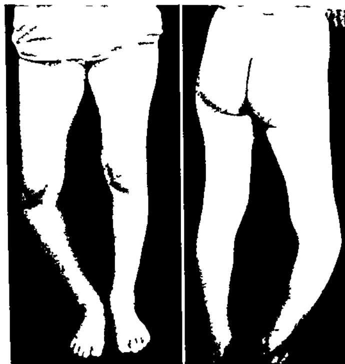


Figure 1 M G born 16 July 1938 Blount's disease in right knee Tibio fibular osteotomy twice last in June 1950 Picture taken ten months after

Again she had relapse of the varus deformity and ten months after the operation the situation was as shown in Figure 1 Quite obviously the varus position was caused by the defect in the tibial meta and epiphysis and the sloping medial tibial joint surface giving poor support to the femoral condyle (Figure 2)

19 July 1951 one year after the last osteotomy an operation was done with elevation of the medial tibial joint surface (description below and Figure 7a b c)

Postoperatively she wore a plaster cast for twelve weeks when active exercise was started Weight bearing was postponed for one year X ray at this time demonstrated a near horizontal medial tibial joint surface (Figure 3) The slight concavity of the surface and somewhat wide medial joint space was believed to be due to the *hypertrophied joint cartilage and medial meniscus which Langenskiöld has shown in arthrographic studies* to be present in Blount's disease At operation this hypertrophy will to some degree prevent maximal elevation of the osseous joint surface but by filling the gap the hypertrophied tissues provide support for the femoral condyle and thus prevent instability The clinical picture one year after the elevation operation is shown in Figure 4

Five years after the operation a roentgenogram showed unaltered position of the elevated fragment and complete assimilation of the transplanted bone with normal



Figure 24 B Roentgenogram of right knee same patient (A) Without weight bearing (B) During weight bearing varus is increased because the defective medial tibial condyle provides poor support for the femoral condyle



Figure 3 Roentgenogram one year after operative elevation of the medial tibial joint surface Consolidation is complete and weight bearing started

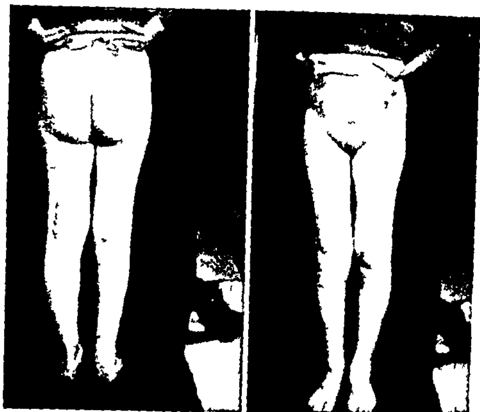


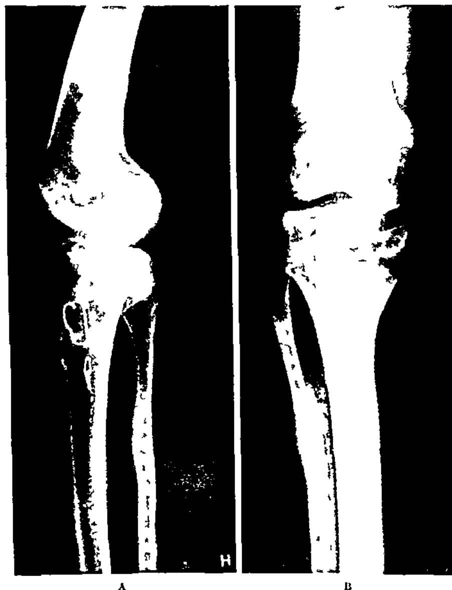
Figure 4 The clinical picture one year after operative elevation of joint surface The right knee shows straight axis no instability normal mobility The visible muscular atrophy is of no consequence and strength is good

bone structures Clinically no varus was seen in the knee which showed full stability and normal mobility The patient had no complaints.

June 1969 eighteen years after the operation a roentgenogram revealed no changes in the operated knee (Figure 5) No arthrosis was seen and no medial sloping Clinically a normal axis of the knee was found (Figure 6) The joint had full stability with normal flexion and extension The patient now has two children, aged two and four years and has gone through the pregnancies without symptoms from her knee

DISCUSSION

In performing an operative elevation of the medial tibial joint surface great care should be taken to avoid the following hazards (1) disturbance of bone nutrition with resulting aseptical necrosis of the elevated fragment (2) lesion of the adjacent tibial epiphyseal line with



A B

Figure 5A and B Roentgenogram of operated knee June 1969 eighteen years after operation The elevated tibial joint surface has unaltered position No signs of arthrosis

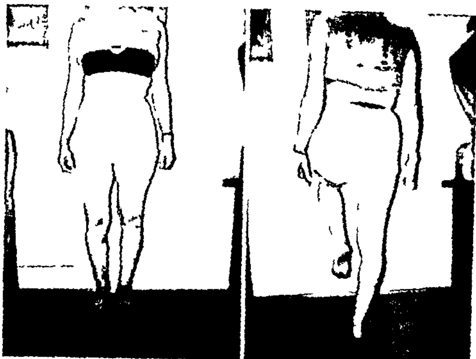


Figure 6 The clinical picture eighteen years after operation No pains the right knee is stable with normal mobility Muscular atrophy is now minimal

ensuing inhibition of growth and varus deformity and (3) secondary arthrosis due to incongruity of articulating joint surfaces No signs of arthrosis were seen after seventeen years in this patient but it should be emphasized that she has not yet reached the age when arthrosis is more common

OPERATIVE TECHNIQUE

The medial tibial condyle is exposed extraperiosteally through a medial longitudinal incision about 12 cm long The fibrous capsule should be stripped only distally to preserve the nutrition to the joint surface The joint is not opened except for a minor slit for the sake of orientation which mainly must depend on roentgenograms and pin markers The chiselling is done parallel to the sloping epiphyseal line at safe proximal distance from the line Care should also be taken to avoid getting too close to the joint surface Several thin bladed chisels 3 cm wide are used simultaneously The chiselling procedes to the midline (X ray

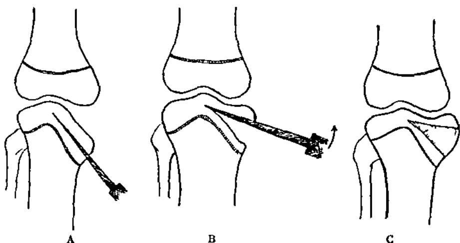


Figure 7 (A) Operative technique The chiselling is done proximally to the epiphyseal line and proceeds to the midline under eminentia intercondyloidea The fragment must not be broken from the bone (B) The fragment is slowly elevated Final elevation is done with wide enough chisel to lift the whole fragment in one piece (C) Transplants from crista ilei large enough to force the fragment in maximal elevation are wedged under the fragment under maximal forced valgus of the knee

control) The fragment is carefully lifted the final elevation being carried out with a wide chisel covering the whole fragment With the knee in forced valgus large bone transplants from crista ilei are wedged under the fragment under maximal elevation The parts of the transplant which are in contact with the spongious bone in the tibia should be decorticated whereas at the edge the cortex provides a firm support for the elevated fragment and should be kept (Figure 3) A plaster cast is applied under forced valgus and kept for twelve weeks Weight bearing is avoided for one year

In cases with a very narrow medial tibial epiphysis lesion of the epiphyseal line at operation may be unavoidable In those cases the operation must be supplemented with lateral epiphysiodesis of tibia and the fibular head

SUMMARY

The varus deformity of the knee in Blount s disease which is caused by sloping of the medial tibial joint surface cannot always be corrected by osteotomies and lateral epiphysiodesis A rational operation then is to elevate the medial tibial joint surface The author did this opera

tion on a thirteen year-old girl in 1951 after two previous osteotomies were followed by relapse of the deformity

Follow up after eighteen years showed unaltered position of the elevated joint surface no arthrosis normal axis stability and mobility of the knee The patient has no pains The operative technique used by the author which differs somewhat from that of Langenskiøld is described

REFERENCE

Langenskiøld A & Riska E B (1964) Tibia vara (Osteochondrosis deformans tibia) *J Bone Jt Surg* 46 A (7) 1405–1420

Acta orthop Scandinav 40 797–806 1970

Department of Surgery Centrallasarettet, Östersund Sweden

THE SKIERS' BOOT TOP FRACTURE

Rising Incidence, Characteristics Treatment

W VAN DER LINDEN

Received 27 viii 68

Among the bony injuries sustained as a result of skiing accidents fractures of the tibio fibular complex predominate These fractures may vary considerably as to their localization the form and extension of the fracture line and the degree of displacement They may be located in the ankle region or they may affect the tibial shaft or the region of the knee Of the ankle injuries the simple fracture of the external malleolus with a spiral fracture line beginning at the level of the ankle joint and extending cephalad and laterally is met so often in skiers that it is sometimes called "the ski fracture (*Bat ner* 1957 *Moritz* 1959 *Ellison Carroll Haddon & Wolf* 1962 *Spademan* 1968) The Bosworth fracture in which the proximal fragment of the fibula becomes impacted with its distal end behind the posterolateral ridge of the tibia (*Bosworth* 1947) is also held to be more or less characteristic for skiers This latter fracture is however seen less often and so are fractures of the tibial malleolus and bimalleolar fractures All these bony injuries in the ankle region of course result from a sudden thrust of the talus against the malleoli Although they are often seen in skiers they are in no way exclusive to the sport but are also met as a result of a variety of other activities

The tibial shaft fractures met in skiers may be divided into spiral and transverse fractures the fracture line reflecting the direction of the forces causing the injury Spiral fractures of the tibio-fibular complex which are sometimes comminuted with butterfly fragments occur as the result of the same rotational force also responsible for the majority of ankle injuries Such forces are likely to arise during down hill skiing when the skier for some reason or other is unable to complete a turn and falls in the direction of his original motion The reason why these forces sometimes result in tibial shaft fractures

tion on a thirteen year old girl in 1951 after two previous osteotomies were followed by relapse of the deformity

Follow up after eighteen years showed unaltered position of the elevated joint surface no arthrosis normal axis stability and mobility of the knee The patient has no pains The operative technique used by the author which differs somewhat from that of Langenskiold is described

REFERENCE

Langenskiold A & Riska E B (1964) Tibia vara (Osteochondrosis deformans tibia) *J Bone Jt Surg* 46 A (7) 1405–1420

more pronounced than that of the other fractures due to ski injuries The difference between the two period is probably significant (χ^2 = 4 46 d f = 1 0 05 > P > 0 01)

Table 1 Skiers tibial shaft fractures treated during two periods

Period	1956–58	1966–68	
Type of fracture			
Low transverse	4	32	36
Spiral and other	36	82	118
	40	114	154

CASE HISTORY

Although a number of patients were very uncertain about their speed and the snow conditions at the moment of the injury and many had great difficulty in remembering how they had fallen the typical case history seemed to be as follows A boy or young adult—*only 6 of the 32 patients were 18 years or older 13 were 12–14 years* old—often with considerable training and equipped with high, hard leather ski boots is more or less rapidly skiing straight down a slope His boots are fastened to the skis with "long thong" straps, "kandahar" bindings, or with a simple form of safety bindings which only release at rotatory stress i e rotation in the plane of the boot bottoms. When suddenly his skis meet an obstacle, his forward motion is abruptly stopped the patient falls forward and is unable to stand afterwards. Only one patient with a boot top fracture had safety bindings with a device enabling release also with a straight forward stress, wh ch actually disengaged at the time of the accident

RADIOLOGICAL CHARACTERISTICS

The radiological features are summarized in Table 2 As seen in this Table the length of the distal fragment measured as the distance between the fracture line and the ankle joint was in most cases less than 6 cm

Backward angulation was found in all but 5 cases This angulation was only slightly indicated (< 5) in 5 cases in the others it was more strongly marked e g in 13 cases it was more than 15 In more than half of the cases there was some forward displacement of the distal fragment As a rule this forward displacement measured less than 1 cm

In many of these young patients there was only slight angulation the fracture having the characteristics of a greenstick fracture Finally in all cases but two both the tibia and the fibula were fractured Figures 1 and 2 show the radiological findings in a 15 year old boy

Table 2 Radiological findings in 32 boot top fractures

Lateral projection			Frontal projection		
	Angulation	Displacement Distal fragment		Angulation	Displacement Distal fragment
Forward	0	18	Medial	4	6
Backward	27	0	Lateral	3	3
None	5	14	None	25	23

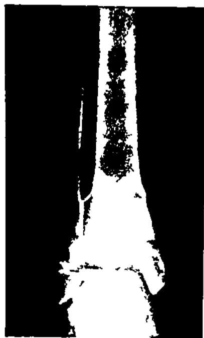
Length of distal fragment

	<3	3–3 9	4–4 9	5–5 9	6–6 9	7–7 9	8–8 9	9 9 9 cm
Number	6	5	8	6	2	3	0	2



Figure 1 Boot top fracture in 15 year-old boy Typical backward angulation Forward displacement of distal fragment only slightly indicated

Figure 2 Same case Frontal projection



TREATMENT

Attempts to reduce fractures with the typical deformity were made under TV fluoroscopy control so that every movement in the fracture could be followed These attempts showed that reduction in many cases was surprisingly easy if the surgeon tried to push and tilt the distal fragment backwards by taking a steady grip on the foot held in extreme plantar flexion Therefore reduction with the foot in plantar flexion performed in general anaesthesia became the method of choice for the treatment of these fractures In order to prevent redisplacement—the fracture often seemed inclined to slip back into its original position—a whole leg plaster was then applied as a rule also with the foot in moderate plantar flexion This was maintained during at least one month in some cases even 2–4 weeks longer After this a new plaster with the foot in the neutral position was usually given

With the exception of two cases in which methods of internal fixation were applied by way of trial all the other cases with a deformity were subjected to this method of manipulative reduction In three cases one of which was severely comminuted the method failed In all the others satisfactory reduction was accomplished

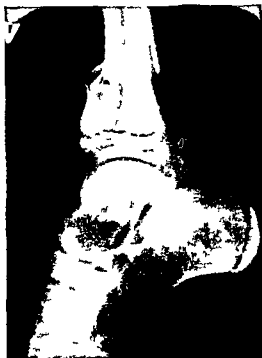


Figure 3 Boot top fracture in 1' year-old boy Slight backward an gulation Moderate forward di placement of the distal fra men The foot is held in plantar flexio to facilitate reduction



Figure 4 Same case after reduction and immobili ation with the foot in plantar flexion

Immobilization with the foot in plantar flexion during one month or even longer did not seem to have any ill effect on the joints of these young people. The reduction in the mobility of the foot tended to disappear soon.

Figure 3 shows a boot top fracture with the typical deformity in a 12 year-old boy. The foot is held in plantar flexion after which the fracture is easily reduced (see Figure 4).

DISCUSSION

A number of factors may be responsible for the relative increase among skiers of low transverse tibial fractures as compared with spiral fractures. There is, for instance, the increasing popularity of down hill skiing, which, at least in Sweden, more and more tends to replace touring and cross country skiing. Further, as a snugly fitting boot facilitates the transmission of every motion of the foot to the ski, which is a prerequisite for its proper control, ski boot manufacturers tend to make the boots ever harder and tighter, e.g. by strengthening the leather with a built in lacing. This, of course, results in a very hard boot top which does not easily yield to pressure. It is also possible that with ski slopes becoming more and more crowded there is a stronger tendency to the formation of ruts and so called moguls (*McIntyre* 1963), i.e. small mounds of snow in which the ski point may get trapped. The relative importance of these factors is, of course, difficult to ascertain.

The analysis of the cases of boot top fractures treated at our hospital during the last 2.5 years showed that not only is there a typical case history but there also is a typical radiological deformity consisting of backward angulation and some forward displacement of the distal fragment. Although boot top fractures are occasionally mentioned in treatises on ski injuries I found only one case with complete roentgenological details in the literature. It is of interest to note that though in this case described by *Clayton* (1962) there also is some lateral angulation and comminution the typical deformity can be very clearly seen.

As no muscles insert into the distal part of the tibia nor arise from it this deformity can not be alleged to muscular force. No doubt the backward angulation has to be ascribed to the forces responsible for the fracture (see Figure 5). With the body in swift forward motion the ski boot foot unit is suddenly halted by an obstacle. The skier

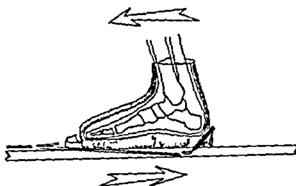


Figure 5 Forces involved in boot top fracture

falling forward breaks his leg against the hard boot top. A backward angulation may arise when he continues his fall if the boot top does not then yield to the pressure. The forward displacement of the distal fragment seen in a number of cases is more difficult to explain. This displacement cannot be due to the forces responsible for the fracture. These forces would instead tend to drive the distal fragment backwards, a displacement seen in none of the 32 cases. It seems possible, however, that the displacement arises when the patient tries to stand up after the injury. With the small distal fragment tilted forward the weight of the body may make the proximal fragment slide backwards in the fracture line.

The fact that the fracture showed a tendency after reduction to return to the original deformity is not at variance with its non-muscular origin. The same tendency is sometimes seen in other fractures in which muscular forces do not play a role, e.g. the simple Colles fracture of the radius. Because of this tendency we preferred to apply the plaster with the foot in plantar flexion. The question arises how the empirical observation that reduction was much easier to accomplish with the foot in plantar flexion is to be explained. Plantar flexion of the foot is halted by ligaments, i.e. the anterior part of the deltoid ligament and the anterior talo-fibular ligament and by the posterior process of the talus thrusting against the tibia's back. It is possible that the pull of the ligaments on the front of the distal fragment and the thrust of the talus against its back tend to counteract its forward tilting. It seems even more important that with

the foot in plantar flexion the surgeon gets a better grip on the small distal fragment and that he obtains a lever which enables him to disimpact the fracture and to force the distal fragment back into position

Finally there is the important question if and how these injuries can be prevented Studies by *Heinkel* (1958) and by *Haddon, Ellison & Carroll* (1962) have supplied convincing evidence of the efficacy of safety bindings Such bindings should release not only with a rotatory but also with a straight forward stress They should furthermore be properly adjusted i e the threshold force needed for release should not be too great Therefore they should also be kept free from wet snow which when frozen to ice at higher altitudes may prevent release

The fact that only one of the patients studied here had effective safety bindings suggests that with such a simple improvement of the skier s equipment much can be achieved in the prophylaxis of the boot top fracture

SUMMARY

A study is made of a series of low transverse fractures of the tibio fibular complex due to ski injuries The incidence of these so called boot top fractures is found to have increased as compared with other tibial shaft fractures in skiers The typical case history is described and an analysis is made of the roentgenological characteristics of this type of fracture From this analysis it appears that in typical cases of boot top injuries there is a backward angulation in the fracture often combined with a forward displacement of the distal fragment A hypothesis to explain this typical deformity is presented Finally a method for the manipulative reduction of these fractures is described According to this method the surgeon should force the small distal fragment backwards by taking a steady grip on the foot held in extreme plantar flexion The fracture is then immobilized with the foot in moderate plantar flexion during at least one month after which a plaster cast is applied with the foot in the neutral position

REFERENCES

Batzner K (19 7) Verletzungen beim Skilauf *Dts h med Ws hr* 82 276–280
Bosworth D M (1947) Fracture dislocation of ankle w th fixed displacement of fibula behind tibia *J Bone J Surg* 29 130 135
Clayt n M L (1967) Ski injuries *Clin O th p* 23 5 16

Ellison A E, Carroll R E, Haddon W & Wolf M (1962) Skiing injuries. Clinical study *Publ Hlth Rep (Wash)* 77 985-991

Erskine L A (1959) The mechanisms involved in skiing injuries *Amer J Surg* 97 667-671

Haddon W, Ellison A E & Carroll R E (1962) Skiing injuries. Epidemiologic study *Publ Hlth Rep (Wash)* 77 975-985

Hemkel K (1958) Statistics of the safety bindings Congress report at Davos Parsenn 1958 as cited by Clayton M L (1962)

McIntyre J M (1963) Skiing injuries *Canad med Ass J* 88, 602-605

Moritz J R (1959) Ski injuries *Amer J Surg* 98 493-505

Spademan R (1968) Lower extremity injuries as related to the use of ski safety bindings *J Amer med Ass* 203 445-450

Westlin N (1968) Nature and frequency of ski injuries *Sv Läk Tidn* 64 1113-1118 (in Swedish)

Acta orthop. Scandinav. 40, 807–816, 1970

Directorate of Accident Insurance, Glostrup Hospital, Surgical Department D (Head: M. Ottsen) and the Orthopaedic Hospital, Department I (Head: A. Bertelsen), Copenhagen, Denmark.

LONG-TERM COURSE IN 119 CASES OF PSEUDARTHROSIS OF THE MEDIAL MALLEOLUS

OTTO SNEPPEN

Received v. 68

In 1890 Bahr described pseudarthrosis of the medial malleolus, and in a subsequent paper (1912) he concluded that pseudarthrosis in this site was a fairly common complication to ankle fracture and that it caused serious symptoms.

Schmidt (1929) and Felzenreich (1937) claimed that they could make a distinction between mobile and immobile pseudarthroses, only the former giving rise to symptoms, the latter being of no prognostic significance worth mentioning. In accordance with this finding Biström (1952) and later Klossner (1962) found that the width of the pseudarthrosis played a prognostic role, a wide pseudarthrosis producing fairly pronounced complaints. These two authors felt, however, that the prognosis also depended upon the site affected in the malleolus, a proximal localization giving rise to relatively severe complaints.

In contradistinction Hendelberg (1943), Storen (1964) and Solonen (1965) found no evidence that pseudarthrosis of the medial malleolus caused any major complaints.

This disagreement concerning the prognostic role of pseudarthrosis in the medial malleolus may be due *inter alia* to the lack of any symptom pathognomonic of this pseudarthrosis. After a complicated fracture of the ankle, therefore, there will always be considerable uncertainty as to whether possible symptoms are due to the malleolar pseudarthrosis or to other sequelae.

To overcome this difficulty as far as possible the assessment must be based upon materials in which the malleolar pseudarthrosis is the only radiological sequel to the fracture.

However, none of the above-mentioned materials had been large enough for such a selective evaluation of the cases of pure pseudarthrosis.

The present investigation was designed to elucidate the long term prognosis of ankle fractures complicated by pseudarthrosis of the medial malleolus on the basis of a follow up study on a large material of pseudarthroses

MATERIAL

During the period 1945–1955 a total of 1717 ankle fractures involving the medial malleolus were notified to the Danish Directorate of Accident Insurance

Among these cases 156 had shown non union of the medial malleolar fragment on X ray films taken after follow up periods exceeding 9 months Accordingly these 156 patients (9 1 per cent of all notified cases) had developed pseudarthrosis of the medial malleoulus.

The follow up examinations were performed by the present author in 1967 At that time 28 of the patients had died Another 6 patients had complicating disease of the same ankle or foot so that it was not possible to assess whether their complaints were due to the pseudarthrosis These 6 patients were therefore not after examined

Out of the remaining 122 patients 119 (97 6 per cent) had a follow up, including X ray examination of the talo-crural and subtalar joints.

The follow up period calculated from the time of the accident until the time of follow up ranged from 8 to 23 years average 15 years. At follow up the patients were from 24 to 84 years of age average 54 years 92 were males and 27 females.

In 47 cases (39 per cent) the patients occupations made great demands on walking function as they had to move on uneven ground scaffolding etc In 40 cases (34 per cent) these demands were more moderate and 32 (27 per cent) of the patients had mainly sedentary work or had retired

SPONTANEOUS UNION

As may be seen from Table 1 about one third of the malleolar pseudarthroses had united the rate of union being somewhat lower at a short and somewhat higher at a long follow up period

Table 1 Incidence of spontaneous union of pseudarthrosis in the medial malleolus and interval between accident and follow up Two cases who obtained union after operative treatment are excluded

Interval between accident and follow up	Pseudarthrosis united	Pseudarthrosis not united	Total
8 12 years	6 (25 %)	18 (75 %)	24 (100 %)
13–15 years	8 (26 %)	23 (74 %)	31 (100 %)
16–18 years	16 (46 %)	19 (54 %)	35 (100 %)
19 23 years	12 (44 %)	15 (56 %)	27 (100 %)
Total	42 (36 %)	75 (64 %)	117 (100 %)

Table 2 Incidence of spontaneous union of pseudarthrosis in the medial malleolus and degree valgus deformity of the hindfoot Two cases who obtained union after operative treatment are excluded

Degree of valgus	Pseudarthrosis united	Pseudarthrosis not united	Total
Slight or none	32 (43%)	43 (57%)	75 (100%)
About 5	4 (27%)	11 (73%)	15 (100%)
More than 5	6 (22%)	21 (78%)	27 (100%)
Total	42 (36%)	75 (64%)	117 (100%)

Thus the malleolar pseudarthrosis shows a marked tendency to unite a tendency which appears to manifest itself for a number of years after its onset

As is apparent from Table 2 there was a relationship between the tendency to healing and the position of the weight bearing hindfoot The greater the valgus deformity the less common the union of the pseudarthrosis in the medial malleolus

This is a remarkable finding which has not been reported previously

Out of the 42 patients listed as having valgus deformity this deformity was bilateral in 35 and presumably congenital In other words there was a pre morbid valgus deformity of the hindfoot of 5 or more in 35 (30 per cent) of the 117 patients

This incidence is high enough to suggest that the valgus deformity also inhibits the early stages of fracture healing in the medial malleolus and thus predisposes to delayed union and pseudarthrosis

Table 3 Incidence of spontaneous union of pseudarthrosis in the medial malleolus and degree of displacement in the ankle joint Two cases with union after operative treatment are excluded

Group A *Cases in which pseudarthrosis in the medial malleolus was the only sequelae*

Group B *Cases with a maximum forward or backward displacement of 2 mm in the pseudarthrosis – but without any other sequelae*

Group C *Cases with other serious sequelae*

Sequelae group	Pseudarthrosis united	Pseudarthrosis not united	Total
Group A	31 (40%)	46 (60%)	77 (100%)
Group B	5 (30%)	12 ([illegible]0%)	17 (100%)
Group C	6 (26%)	17 (74%)	23 (100%)
Total	4[illegible] (36%)	75 ([illegible]4%)	117 (100%)

Displacement at the site of the pseudarthrosis or more pronounced sequelae to the fracture also adversely affected the tendency to spontaneous union as shown in Table 3

OSTEOARTHRITIS

Among the 119 patients 53 (45 per cent) had osteoarthritis of the talocrural or subtalar joint This incidence is no higher than may be expected following conservatively treated ankle fractures of the same severity but without complicating pseudarthrosis of the medial malleolus (Magnusson 1945 Storen 1964 Kett 1965)

It is apparent moreover (Table 4) that the incidence of osteoarthritis was even higher in the cases where the malleolar pseudarthrosis had united

Table 4 Incidence of osteoarthritis in the talocrural joint and/or subtalar joint and healing of pseudarthrosis Only cases of pure pseudarthrosis are included (Groups A and B Table 3) Mild osteoarthritis means slight narrowing of joint space and/or slight but distinct lipping at the articular margins

Status of pseudarthrosis	Degree of osteoarthritis			Total
	None	Mild	Pronounced	
United	21 (55 %)	10 (26 %)	7 (18 %)	38 (100 %)
Not united	41 (72 %)	11 (19 %)	6 (10 %)	58 (100 %)
Total	62 (65 %)	21 (22 %)	13 (14 %)	96 (100 %)

Accordingly pseudarthrosis of the medial malleolus does not appear to contribute to the development of osteoarthritis in the ankle joint

SYMPTOMS AND SIGNS

For a year or two after the trauma about 80 per cent of the pure cases of pseudarthrosis (Table 3 Groups A and B) had had fairly severe complaints which had considerably interfered with the rehabilitation in about half the patients (Sneppen 1967) In practically all cases however the complaints had dwindled to a minimum Seven pseudarthroses had been treated by operation at an early stage of the course but none of the other patients had received any major treatment of their ankle complaints

Therefore considering that 38 (40 per cent) of the cases of pure

pseudarthrosis were still doing heavy work at the time of follow up the symptoms must be characterized on the whole as mild

Table 5 Existence of pseudarthrosis and nature of complaints in cases of pure pseudarthrosis (Table 3 Groups A and B) Only cases without osteoarthritis are included

Status of *pseudarthrosis*	No of *cases*	Pain	Stiffness	Instability	Distinct symptoms *at medial* malleolus
United	21	9	7	1	2
Not united	41	24	8	7	5

From Tables 5 and 6 it is evident that the malleolar pseudarthrosis did not give rise to any characteristic symptoms or signs However instability and tenderness of the malleolus were of a somewhat increased incidence in the group of pseudarthrosis but the numerical values are too small to form the basis of conclusions

Table 6 Existence of pseudarthrosis and nature of objective changes in case of pure pseudarthrosis (Table 3 Groups A and B) Only cases without osteoarthritis are included

Status of pseudarthrosis	No of cases	Muscular atrophy	*Limitation of movement* Talcocrural joint	Subtalar joint	Tenderness at the medial malleolus
United	21	8	12	3	1
Not united	41	5	18	3	6

PROGNOSTIC ROLE OF THE MALLEOLAR PSEUDARTHROSIS

In Tables 7 and 8 the symptoms and signs in the united and non united cases are compared

A good subjective result means that the patient was symptom free or had only negligible complaints when exposed to major strain A fair result means more pronounced complaints on special strain or changes in the weather If more severe complaints were present the result was classified as poor

It may be seen from Table 7 that the subjective status was approx

Table 7 Existence of pseudarthrosis and subjective results in cases of "pure pseudarthrosis" (Table 3 Groups A and B) Only cases without osteoarthritis are included

Status of pseudarthrosis	Subjective results			Total
	Good	Fair	Poor	
United	12 (57 %)	3 (14 %)	6 (29 %)	21 (100 %)
Not united	23 (56 %)	13 (32 %)	5 (12 %)	41 (100 %)
Total	35 (56 %)	16 (26 %)	11 (18 %)	62 (100 %)

imately the same whether or not the malleolar pseudarthrosis had united

A good objective result means normal findings at the physical examination A fair result means tenderness at the malleolus and/or slightly limited mobility in the ankle joint but not to less than two thirds of the mobility on the other side In the event of severe objective changes the case was assigned to the poor results

Table 8 Existence of pseudarthrosis and objective results in cases of pure pseudarthrosis (Table 3 Groups A and B) Only cases without osteoarthritis are included

Status of pseudarthrosis	Objective results			Total
	Good	Fair	Poor	
United	9 (43 %)	7 (33 %)	5 (24 %)	21 (100 %)
Not united	22 (54 %)	17 (41 %)	2 (5 %)	41 (100 %)
Total	31 (50 %)	24 (39 %)	7 (11 %)	62 (100 %)

Table 8 shows that the objective status too was approximately the same whether or not the malleolar pseudarthrosis had united

In other words pseudarthrosis of the medial malleolus appears to play no role in the long term prognosis of ankle fracture

As mentioned in the introduction it has been claimed by several previous authors that the width of a malleolar pseudarthrosis and thereby its mobility as well as its localization in the malleolus are of decisive prognostic importance

These factors are analysed in Tables 9 and 10

The basis of the classification is the same as used above except that the subjective assessments are considered together the poorer of the two in each case deciding the classification

Table 9. Width of the pseudarthrosis and clinical results in cases of pure pseudarthrosis without osteoarthritis

Width of pseudarthrosis	No. of cases	Subjective results		Objective results	
		Good	Not good	Good	Not good
2 mm	16	9	7	8	8
3–4 mm	15	10	5	8	7
Over 4 mm	10	4	6	6	4
Total	41	23	18	22	19

In accordance with the lacking importance of the malleolar pseudarthrosis in the long term prognosis of the ankle fracture it was found also that neither the width nor the localization of the pseudarthrosis in the malleolus had any demonstrable influence upon the symptoms or signs.

Table 10. Localization of pseudarthrosis in the medial malleolus and clinical results in cases of pure pseudarthrosis without osteoarthritis

Localization of pseudarthrosis in malleolus	No. of cases	Subjective results		Objective results	
		Good	Not good	Good	Not good
Base	9	6	3	4	5
Middle	27	14	13	15	12
Apex	5	3	2	3	2
Total	41	23	18	22	19

Lastly it should be mentioned that the present material did not include any case of dislocation in a pseudarthrosis not even where it was wide and localized at the base of the malleolus. Thus there seems to be no risk of such dislocation although this has been reported previously (Rostock 1938).

DISCUSSION AND CONCLUSION

In the present study a 9 month follow up period was set as the limit between delayed union and formation of pseudarthrosis. On this background the author found the incidence of pseudarthroses to be 9.1 per cent in ankle fractures involving the medial malleolus. This incidence accords with that usually reported in the literature (Hendelberg 1943, Kristensen 1953, Bistom 1962 and Klossner 1962).

extreme outwards rotation Thus fixed the child will actively correct the club foot by kicking Denis Browne himself improved his original splint and many other variations and improvements of the splint have been described (*Thomson* 1955 *Jergensen* 1913 *Bell & Grice* 1944 *Bluhm* 1947 and *Gibson* 1954)

During the last decade the use of the Denis Browne splint has been abandoned in a number of countries Thus in 1964 *Kite* who had tested the splint writes that a simple fixation of the foot to a stiff metal plate and a forced correction outwards of the foot do not exert pressure at the site of the deformity Insufficient correction of the hind foot and development of rocker bottom foot are among the poor results

At the Orthopaedic Hospital in Copenhagen the Denis Browne splint was used systematically for a number of years but during the past ten years its use has been given up because of insufficient correction of the hind foot and false corrections resulting in rocker bottom foot Since 1956 the principle of treatment has been daily manipulation therapy followed by soft tissue operation in case the manipulation therapy does not lead to good results within a few months As supplement to the treatment splints of the retaining type are being used during the first year of life the plexidur splint designed by *Hjalmar Larsen* (1967) and after the first year a leather night splint As a link in the treatment these two splints have been satisfactory generally speaking but they have certain disadvantages

Because of the thermoplastic properties of the material the plexidur splint can be remoulded easily and corrections be made to follow up results obtained in the course of the manipulation therapy Herein lies its greatest advantage but it entails frequent and time consuming corrections of the splint especially during the first months of manipulation therapy

When the child reaches the age of 10–12 months, the plexidur splint is usually replaced by a rigid leather night splint Corrections when indicated are almost impossible to make in this type of splint (apart from lengthening) and furthermore the material does not meet hygienic requirements

In the light of these disadvantages a programme was initiated in 1961 with the object of designing a new type of splint which had a retaining but at the same time a correcting effect on the components equinus varus and adductus Corrections should take place corresponding with axes at the various movements in the ankle joint the subtalar joint and the mid tarsal joint

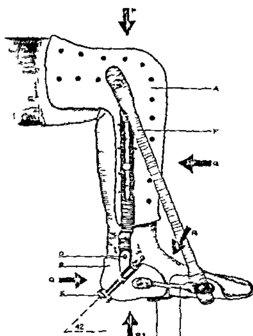


Figure 1

As ankle joint a one axis joint was used with the axis positioned horizontally at the distal part of the lateral malleolus as this made an acceptable compromise between the axis for plantar flexion and the axis for dorsi flexion as described by *Hicks* (1953) (Figure 1 (D))

As an axis for pro and supination the compromise axis described by *Manter* (1941) was employed It forms an angle of 42 degrees with the horizontal plane and deviates 16 degrees medially in relation to the longitudinal axis of the foot This idea which is the most essential of what is new in the splint originates from a work by *Desai & Henderson* (1961) in which they use a mechanical analogue of the axes of the subtalo joint and the talocrural joint in connection with a drop foot brace Individual alignment of the subtalar axis is not possible when making splints for children therefore the angle 42–16 degrees is used as standard (Figure 1 (E)) Consequently a mechanical analogue does not come in in all cases but on the basis of our observations of the pro and supination curve we consider possible deviations acceptable Ab- and adduction occur around an axis corresponding to that of the mid tarsal joint (Figure 1 (C))



Figure 2

The dynamic night splint consists of a foot plate (Figure 1 (B)) and a knee crus part (Figure 1 (A)). The connection between these is formed by the mechanical talocrural joint. The foot plate is formed to support calcaneus. On its lateral side it supports os cuboideum and thus exerts the necessary counter pressure for abduction of the fore foot. The knee crus part is fitted to the anterior side of crus and continues on the femur. The femur part forms an angle of 90° with the crus part.

To ensure the necessary fixation of the foot to the foot plate is essential. Decisive for a fixed position are the pressures represented by the vectors P P_1 and Q Q_1 seen in Figure 1. The vector R indicates a pressure exerted by a piece of felt placed over the dorsal side of the foot (Figures 2 and 3).

The splint is fixed to the leg by a wrapped bandage (Figure 1). Pro- and supination can occur only about the mechanical subtalo joint axis. Dorsal flexion is possible only about the mechanical talocrural joint axis. A dorsal flexion is not possible in the Chopart's joint.

Correction of the foot in pronation and dorsal flexion is influenced by an elastic pull on the lateral side of the splint as shown in Figure 1 (E) and Figures 3 and 4. Owing to the position of the elastic cord

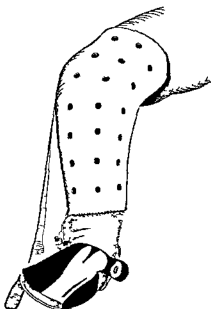


Figure 3

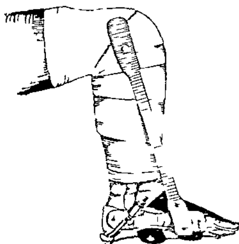


Figure 4



Figure 2

The dynamic night splint consists of a foot plate (Figure 1 (B)) and a knee crus part (Figure 1 (A)). The connection between these is formed by the mechanical talocrural joint. The foot plate is formed to support calcaneus. On its lateral side it supports os cuboideum and thus exerts the necessary counter pressure for abduction of the fore foot. The knee crus part is fitted to the anterior side of crus and continues on the femur. The femur part forms an angle of 90° with the crus part.

To ensure the necessary fixation of the foot to the foot plate is essential. Decisive for a fixed position are the pressures represented by the vectors P P_1 and Q Q_1 seen in Figure 1. The vector R indicates a pressure exerted by a piece of felt placed over the dorsal side of the foot (Figures 2 and 3).

The splint is fixed to the leg by a wrapped bandage (Figure 4). Pro- and supination can occur only about the mechanical subtalo joint axis. Dorsal flexion is possible only about the mechanical talocrural joint axis. A dorsal flexion is not possible in the Chopart's joint.

Correction of the foot in pronation and dorsal flexion is influenced by an elastic pull on the lateral side of the splint as shown in Figure 1 (E) and Figures 3 and 4. Owing to the position of the elastic cord

This was however corrected by means of a softer elastic material

In a couple of cases the axis of the ankle joint was placed too distally and in other cases the heel counter was too wide and too low to afford satisfactory support to the heel

As to the results and the advantages contained in this dynamic splint over a retaining splint no exact figures can be reported Treatment with this splint is only part of the entire treatment and comparison with a material for which only retaining splint types have been used requires a larger material unless completely uniform cases with the same primary treatment have been dealt with

When the disadvantages mentioned have been countered this type of splint should make false corrections impossible It is able to influence function and the mobility counteracts contractures of ligaments and joint capsules at the ankle joint the subtalo joint and the mid tarsal joint Although there is no evidence it is the opinion of the parents of the patients and the therapists that the dynamic night splint influences the tension in the tissues the muscles and the ligaments in such a way that the foot becomes softer at a much faster rate than was the case when a retaining type of splint was applied This coincides with the opinion of the authors based on similar observations

On the basis of the present results no disadvantages have been observed which contra indicate future use of the splint From a practical and economic point of view it is the plan to prefabricate the splint in order to make delivery and exchange of parts of the splint possible in a minimum of time Moreover it will be possible to reuse the individual parts of the splint

After having seen a dynamic splint applied with incorrectly positioned mechanical joints it is necessary to stress that only an entirely correctly designed splint of the dynamic type can offer advantages over a splint of a solely retaining type

SUMMARY

Different types of splints that have been used for the treatment of club foot are discussed and an account given of the reasons for wanting a new type of splint a dynamic splint which not only retains but acts as a permanently redressing splint

A condition for better results with this type of splint than a solely retaining splint is that in the construction the anato

the foot is taken fully into account thus that motions made possibl by the splint in the ankle joint the subtalo joint and the midtarsa joint must almost coincide with the corresponding axes The calcul tion of and the average values for the position of these axes ar mentioned A detailed technical description of the splint is given

On the basis of a clinical material comprising 41 patients and 6 splints applied after the age of 3 months in the period August 196 September 1967 the experience gained and the technical problem encountered and their solution are discussed

The conclusion arrived at is that properly applied this splint is value in future treatment of club feet and from an economic/pra tical point of view it is also favourable The advantages over th solely retaining splint are mentioned The importance of an absolute correct construction of the splint is stressed

REFERENCES

Barwell R (1865) *On the cure of club foot without cutting tendons* R Hardwi London pp 61–66 126 149

Bell J F & Grice D S (1944) *Treatment of congenital talipes equinovarus with* modified Denis Browne splint *J Bone Jt Surg* 26 799 811

Bluhm M (1947) Modification of the Denis Browne splint *J Bone Jt Surg* 248 249

Brown L T (1936) The treatment of club feet *J Bone Jt Surg* 18 173 1?7

Browne Denis (1937) Modern methods of treatment of club foot *Brit med J* 570 572

Desai S M & Henderson W H (1961) *Engineering design of an orth p lic bra* Biomechanics Laboratory University of California San Francisc and Berkel

Gibson A (1951) A universal joint club foot splint *J Bone Jt Surg* 33 A 658 6

Hicks J H (1953) The mechanics of the foot *J Anat* 87 345 357

Jergensen F L (1943) The treatment of unilateral congenital talipes equinovar with the Denis Browne splint *J Bone Jt Surg* 25 185 187

Kite J H (1964) *The club foot* Grune & Stratton New York

Larsen I Hjalmar 1967 Personal communication in Reimann Inge (196) Co genital club foot Munksgaard Copenhagen

Levy S 1893 The treatment of the club-foot *Bull Larger Ser* 4 46 52

Manter J T (1941) Movement of the subtalar and transverse tarsal joints *An Rec* 80 397 410

Sayre L A 1869 *A practical manual of the treatment of club feet* Appleton & C New York

Scarpa A 1804 *Über die angeborenen krummen Füsse der Kinder* (translated Malfatti Vienna pp 1 38

Sofield H A (1931) Flat tie traction assisting correction of club foot *J Bone Jt Surg* 13 283 286

Thomson S A 1955 Modified Denis Browne splint for unilateral club foot to protect the normal foot *J Bone Jt Surg* 37 A 1287 1 87